TRANSACTIONS

OF THE

AMERICAN FOUNDRYMEN'S ASSOCIATION

VOLUME XXI

EDITED BY
RICHARD MOLDENKE
SECRETARY

PUBLISHED BY THE ASSOCIATION
WATCHUNG, N. J.
1913

EARLY ORNAMENTAL STOVE FRONTS AND OVEN TILES.

Two richly illustrated articles on the above subject have recently appeared in *Stahl und Eisen* (Nos. 9 and 13, 1912). Dr. Otto Johannsen writes on the technical development of these oven tiles, and Director J. Lasius takes up their production from the standpoint of the historical art critic.

In the middle ages—quantity castings production being unknown—when a bell was wanted, a monk would form up his mold in clay. The gunsmith would go about making a cannon the same way, and where ornamental pieces were desired, whether in cast iron or bronze, the lost wax process was resorted to, as patterns and cores had not yet been sufficiently developed by necessity.

In the production of oven fronts, stove tiles, etc., open sand work answered very well, and all that had to be done was to prepare a level bed, surround it with walls of molding sand, and cut into these a channel allowing surplus metal to flow away leaving the casting of the desired thickness. It was but natural that such a level bed of sand afforded an unusual temptation for artistic endeavor on the part of the molder, and hence he would imprint his pipe, or roll of tobacco, and even his outspread hand into it, the subsequently cast plate giving faithful reproductions. This tendency is noticed even to-day in some German works, where in casting open-sand furnace plates, the men will ornament them as indicated above. The application of the rope's end in this manner was a favorite decoration in the sea-coast towns, as one can still see in their building tiles, and particularly in a very notable example of the blacksmith's art in the rope and sailor's knots of wrought iron winding around the pulpit of the Lübeck cathedral. The family stove, therefore, oftentimes reflected the taste of the region.

As time passed on, an ornament in relief by an artist was pressed directly into the sand, and practically became a pattern, as it could be repeated. The idea of such a pattern, when used as a die, was known to the old Romans, for on some of their lead

sarcophagi one can see the repetition of imprints of an ornamental die, unevenly spaced and lines overlapping. One of the finest examples of this repetition work in the sand bed prepared for an oven plate, is seen in Fig. 1, which dates back to 1592 and was made at Neuhütte (New Furnace) near Strassebersbach, in Germany. This plate is a representation of the Resurrection, and every part of it was made by impressing specially made dies into the sand. Even the frames were made with small sections of molding, the sand being compressed a little at a time. It

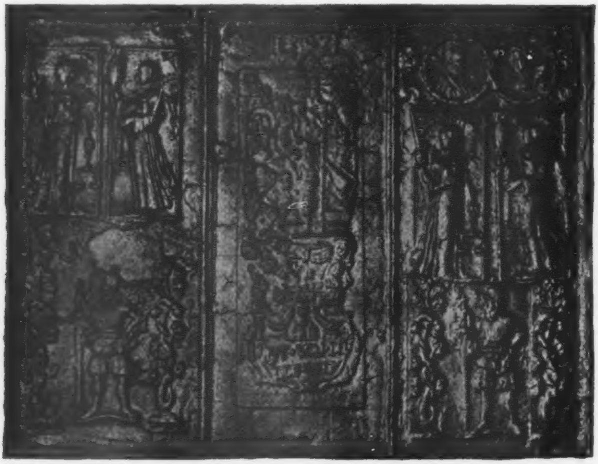


FIG. 1.

was the day of the wood-cut and ornamental carving of interior decoration of churches and homes, and hence the foundryman had an abundance of material to work with in getting out the few castings required in as ornamental a form as possible.

If the patterns thus worked out did not fit the required job so far as size was concerned, the foundryman (or rather furnaceman in those days) would fill in with other ornaments, or utilize the pattern twice, as may be seen in Fig. 2, which is a reproduction of the famous Emperor Maximilian plate. Sometimes it is almost impossible to determine whether such loose patterns—

or wooden dies, as it were—have been used. However, in Fig. 3, representing St. Martin cutting his mantle for the beggar, this may be distinctly noted, as the die and sand-bed levels do not correspond.

Later on, one would affix a series of the above mentioned dies upon the same plate used for pattern purposes, and in this way get out very creditable castings. Witness Fig. 4, made

FIG. 2.

in the eighteenth century, which shows up splendidly, with only one ornament indicating a shifting of the die about its point of fastening.

The last stage came about when the pattern for a given casting was made in its entirety, and no loose or separately attached parts were employed. Then the work became one of high art.

Dipping into the history of the art of iron founding, we find, according to L. Beck (the German authority) that plain, flat

plates used for cooking purposes—laid upon a brick hearth—were first used in 1468. The first mention of an iron stove dates back to 1474, though this is hardly the actual origin of that useful piece of household furniture, for in the records of several years thereafter a number of citations may be found. As a matter of fact, however, the beginning of the iron foundry as a regular business can be fixed at the year 1500. At first the stove (far

FIG. 3.

different from our modern development) is found in the castle of the ruling noble. Next one potentate would send it as a present to the other. Monastery and convent would purchase this foundry product, or more likely receive it as a votive offering. Next the rich cities would place the stove in their representative edifice—the Rathaus (City Hall). The elite of the cities had to have it, and fifty years thereafter we find the farmer installing his heavy

castings and enjoying life better than ever before. When this period of quantity production arrived, we find the quality of the art end of it dropping down as patterns were made to last as long as possible, which meant patching up much as it does to-day. The requirements regarding ornamentation, however, were unique. For instance in the almshouses a stove would regularly show the "Cruse of the Widow", while in the vineyard regions of the Saar and the Mosel, the "Wedding of Canaan" predominated, inci-

FIG. 4.

dentally showing the interest taken even in those early days in turning water into wine.

In the early part of the nineteenth century patterns began to be made of metal, and were highly finished. Several of these are in possession of the Society of German Engineers. One is shown in Fig. 5. This metal pattern is of brass. Occasionally patterns are found on which an ornament is repeated, showing that a master pattern was made use of.

Nearly every German blast furnace establishment turned out these stove tiles. The collection above mentioned has them from the Harz, Alsace, Nassau, Saarbrück, and Würtemberg, and has them still to get from Brunswick, Saxony, Silesia, Siegen, Eifel and Hunsrück to complete the list. A conspicuous industry along this line existed in Sussex, England, and the Norse countries of Europe furnished another set of examples.

Unquestionably the proficiency in the art of molding must have been of a high order in these later days. Collections of

FIG. 5.

wooden ornamental patterns of the eighteenth century are still in existence; in fact, a splendid collection of patterns of this baroque period of ornamentation was found by Privy Councillor Boecking in the garret of the old mining school near Saarbrück and rescued from destruction. Fig. 6 shows such a pattern, made of oak and in an excellent state of preservation.

In the molding up an exactly level sand bed was first prepared, at each side of which was located a planed rail of cast or wrought iron some six inches high, and firmly attached to a

foundation. On this bed came charcoal or coke cinders, upon which molding sand was riddled to a depth of about three-quarters of an inch. This loose sand was spread evenly by a wooden lath, and then compressed by means of wooden rolls of various diameters, the trunions of the rolls running over the rails. The patterns were next pressed into the sand bed, the spirit level being used to get things exact. Sand was packed between the pattern and the rails—the latter being perforated to allow venting of the sand bed. After lifting the pattern, the mold was dusted

FIG. 6.

with charcoal or coke dust, and after arranging for the overflow level, the mold was poured. In order that these comparatively thin castings might be run with complete corners, the molten metal had to be pushed into them with a stick having a cross piece attached to the end, this wooden cross piece being previously dipped into water. The gases were ignited to avoid explosions. As soon as the metal had set, the molder would put weights upon it to prevent warping. In the case of patterns with detachable ornamental parts, these were unscrewed from the board and

"returned" again, pressing the coke dust well into the sand, so that sharper outlines might be had on the castings. All shot was carefully removed from the molding sand, this being held responsible for molding losses.

After a sufficient number of these plates had been cast, they were put together in similarly cast frames or on iron angles, and in this way a stove constructed that often reached a height of thirty-seven feet—as, for instance, the fine ornamental heating stove of the "Artushof" in Danzig. The oldest example of a complete stove in perfect preservation is in the fortress Coburg, this dating ostensibly back to 1485, but in all probability to 1500.

FIG. 7.

A very interesting series of analyses of these oven tiles (in the collection of the Halbergerhütte, Germany) is given—these dating from 1508 to 1811. The silicon runs from 0.65 to 1.68; phosphorus from 0.26 to 1.53; sulphur from 0.05 to 0.12; manganese from 0.26 to 1.50; total carbon from 3.44 to 4.00, graphite being 2.45 to 3.60. The combined carbon ran from 0.12 up to 1.22. Until the nineteenth century stoves as well as all commercial iron castings were made by the blast furnaces. The cities which had foundries cared only for jobbing work, and nearly all of this was of brass or bronze, only an occasional stove being made there. In regard to the operation of the blast furnace in those early days

much has yet to be discovered. Only fine, tough gray charcoal iron was used for stoves.

In the very early days the casting of bronze candelabra, baptismal fonts, and other ornamental church and house furnishings, was in the hands of a guild called the "Apengeter" who thrived in the Hansa and other cities and in the early years of the fifteenth century already possessed rules and regulations. A Hans Apengeter van Sassenland made some of the castings mentioned above in the early fourteenth century. The name Apengeter is interesting to the philologist, and its derivation without doubt comes from the strange figures of animals these early artisans turned out as ornaments on their castings. "Apen" is a corruption of "Affen," or monkeys. "Geter" is probably a corruption of "giesser" or founder. Hence "monkey-founder" is the origin of a then and now highly respected family name.

Turning to England we have a very fine tile cast by Ironmaster Richard Lennard at Brede Fournes (Sussex), and dating to the year 1636. It is shown in Fig. 7. The tile exhibits the founder himself and holding his sledge. A weighted mold and ladle are at his feet. At the left hand is a heavily ringed blast furnace with the modern inclined hoist. Above is seen his coat of arms—the hammer, tongs, rammer, and weight. At the lower right-hand corner is a finished oven plate with his monogram R. L., above which is a female animal of wonderful shape—perhaps a "pig" emblematical of the art of founding, and finally, in the upper right-hand corner on a shelf, a bowl, pitcher, and large wineglass showing that the dust and heat of the foundry engendered thirst even in those days.

It is a pity that during the "high" period of 1873, in Germany, an enormous quantity of these old oven tiles and plates went into the cupola, the country being combed clean. In spite of this, however, very fine collections exist in Ilsenburg, Eich (Luxemburg), at the Halberger furnace, and the historical museums of Metz, Nancy, Lübeck, Brighton, Hastings, and in other lesser known cities having men whose artistic taste ran toward the collection of this class of material.

One of the interesting questions that come to one's mind in studying the artistic side of the productions described above, is who furnished the original drawings and designs which have

been translated into iron by the deft hand of the skilled furnaceman-molder. In the sixteenth century and somewhat later the length and breadth of Germany and contiguous countries was filled with hard-working creative artists properly called the "Lesser Masters." These men, whether in painting, sculpture, or exquisite carving of wood and ivory, copper-plate etching, or in

FIG. 8.

gold and silversmithing, managed to turn out designs without number, which served to stimulate the foundryman into contributing his share to the general advancement of the times. A pertinent example is found in the cast plate marking the grave of Margaretha von Elts in the church at Boppard. The relief shown on the plate, made by Loy Hering in 1519, exemplifying the Trinity, is

easily recognized in the wood-cut of Albrecht Dürer. Fig. 8 shows the plate and Fig. 9 the Dürer wood-cut. In fact, Albrecht Dürer's designs were so varied in character that they were copied widely and for all purposes.

In the frontispiece accompanying this article we have a very fine oven plate by a famous artist of the middle sixteenth

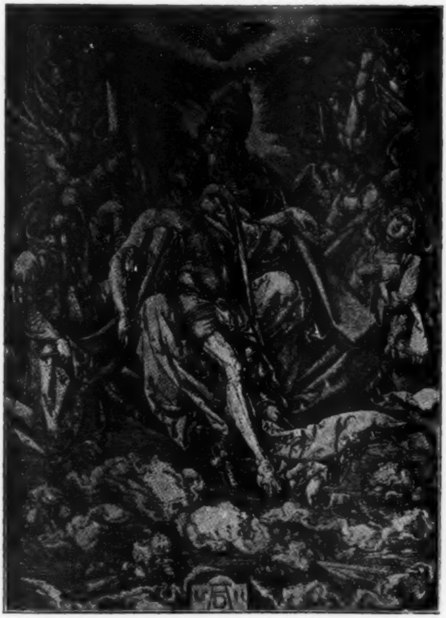


FIG. 9.

century named Philipp Soldan. It is owned by the Historical Society of Marburg (Hesse). This artist is oftentimes mentioned in the financial accounts of the monastery Haina in Hesse, being paid for special artistic carving of wooden patterns for their blast furnace casting work. The picture represents the creation of Eve on the left, and the birth of Christ on the right, both separated

by an early renaissance column of exquisite proportions. The symbols of the Evangelists may be seen, as well as a fine ornamental upper finish. Below the two medallions are five figures with the names inscribed on each pedestal (indistinct). These are Jesus, Moses, Lucretia, Isaiah, and David. The faces of the two medallions are specially interesting. That of God the Father is plainly after Dürer. On the other hand, the Virgin shows the influence of Hans Daucher.

FIG. 10.

One of the very fine examples of Soldan's work (dated 1550) is a plate illustrating the parable of Dives and Lazarus. The broad ostentatious figure of Dives is well executed, his raiment the richest of the times. The table is set with the delicacies of the season—fish, a roast, the goblet. Alongside a richly dressed lady of the period, holding a string to which is attached the pet animal shown (a meerkat). The servant brings a covered tureen, musicians are in the rear discoursing with flute and violin, and

the majordomo of this patrician house is about to drive a poor man away from the door with his wand of office. He, Lazarus, but scantily covered and with the dogs licking his wounds, has seated himself at the threshold. The contrast between the two men is highly marked. The future is vividly shown, for the devil takes Dives' soul into his jaws and the fat drips down (upper left), whereas Lazarus' soul is conducted by angels to the lap of his heavenly Father (lower right to upper left). There are many details in this plate which are of highest interest to the art student, who can trace the late gothic, early renaissance, and later period points in the drinking canteens, clothes, and other ornaments.

It would carry us too far to go into the many splendid examples of the founder's art of these early days. Suffice it to lay emphasis upon the urgent request of both writers of the articles reviewed herein, that our historical material be preserved more conscientiously, or if this be impossible, that at least photographs be taken for the information of future generations.

MOLDING SAND TESTS.

INTRODUCTION.

Among the investigations carried out under the auspices of the American Foundrymen's Association, none would seem to be of such vital importance to foundrymen as a study of the molding sands they are using.

One of the important points of foundry economy which has received but little attention is the efficiency of molding sand. That is to say, the tonnage of molten metal it is possible to pour successfully into work for each ton of new sand put upon the piles. By this tonnage of molten metal is meant the good and bad castings, the gates, sprues, over-iron poured into sand pigs, etc. In short, the metal melted in the cupola. By the new sand is meant that which is brought into the foundry daily to keep up the sand piles properly.

Investigation along this line has shown that widely varying results are obtained—doubtless due to general cheapness of molding sand in the foundry districts—and consequent inattention to the matter except when the disposal of the burnt sand becomes an acute question. That there is much to be learned herein is shown by the fact that for the same general line of castings one establishment obtains a sand ratio of sixteen tons of iron poured to one of new sand brought in, whereas another comes out as low as four to one, or paying for four times as much sand per annum for the same tonnage of metal melted, and proportionally very much more when the tonnage of castings actually sold is considered.

At the time these molding sand tests were undertaken, requests for nail keg samples were sent to all the dealers in this commodity, as well as to the members of the Association, of whom many were using local sands of their own. A very generous response was the result, and the tests made are therefore based upon the study of eighty natural molding sands, most of them well-known standards. In addition there have been prepared twelve combinations of sand and fire-clay, to form a series of artificial molding sands.

Each firm or foundry contributing sand has been given a letter of the alphabet as a designation. The names to correspond are known only by the respective donors, so that they might judge their sands in comparison with all the others. In this way no advantage could be taken in the way of competition. A sand may be traced through all the tables of tests and its value seen by comparison.

The physical tests of these ninety-two sands were conducted by the Secretary of the Association, while the rational analyses, the mineral determinations, photographs under the microscope, etc., were performed by the gentlemen whose names are at the head of their respective reports.

In return for making the physical tests of the molding sands of the State, the Geological Survey of Ohio very courteously contributed a study on the formation of molding sands and their mineral characteristics, this being the opening chapter.

As the work progressed new lines of investigation suggested themselves, and these were taken up as time allowed, and indeed it may be that supplements to this report will eventually follow as the subject opens up more fully to the methods of more advanced analysis.

THE SECRETARY.

MOLDING SAND TESTS.

Mineral Characteristics of the Molding Sands.

By D. Dale Condit, Columbus, O.

Courtesy of the Geological Survey of Ohio.

I. Principles of Sedimentation.
II. Properties of Minerals.
    Methods of Examination.
    Description of Minerals.
    Significance of Color.
    Relation of Mineral Content to Chemical Analysis.
    Refractory Properties of Sands.
III. Mineral Constituents of the Molding Sands Tested.
    Natural Molding Sands.
    Artificial Molding Sands.

I. Principles of Sedimentation.

Moving water in streams and along the shores of seas is the great agency in the transportation and deposition of sands. Currents bearing suspended materials exercise a sorting action during deposition of their loads. With materials of the same density the sorting will grade the deposit according to the size of the particles. With materials of different densities, larger particles of lighter minerals will be thrown with smaller particles of heavier minerals.

During transportation sand grains mutually abrade one another and the tendency is to reduce any angularities and produce a rounded grain. In general, the larger grains of sand are apt to show the most evidence of rounding. Of grains of equal size, the heavier are the more rounded. With the same size and specific gravity, the softer show more rounding, and finally those sands which travel the farthest are the most rounded.

Wind is another important factor in the transportation of sand. The assorting power of wind is much greater than that of water and produces a sand of very uniform sized grains. Rounding of the particles by abrasion also takes place more rapidly in air than in water, as the impact is greater. Soft minerals are therefore reduced to dust more rapidly and are blown away, leaving the more resistant minerals behind. Wind action produces rounding in grains much smaller than one two-hundred and fiftieth of an inch in diameter, which is the smallest sized grain affected by the rounding action of water. Hence when a sand is found that has well-rounded grains smaller than this size, the conclusion is that the wind has played a part in its transportation and deposition.

There are three common types of sands, namely: (1) rock sands, or old sandstone formations which are continuous over large areas and which are usually more or less firmly cemented by iron oxide, silica, or some other bond; (2) residuary sands derived by weathering and erosion of the sandstone and other rock; and (3) glacial drift sands derived by assortment of glacial drift material by wind and water currents.

Most of the recent sand deposits of the northern part of United States are due directly or indirectly to glaciation. In comparatively recent geological time, much of the northern part of our country was invaded by a great ice sheet, which had its source in the highlands of Canada. The ice front advancing from the north carried along much soil and rock that lay in its path. A large part of the rock was reduced to sand by the grinding action of the ice. The resulting material—a heterogeneous mixture of boulders, clay, sand and gravel—is called *glacial drift.* During the final retreat of the glaciers, there were formed many recessional lakes around the ice margin. Numerous rivers fed by the melting ice flowed into these lakes, carrying the finer material of the drift and laying it down as gravel, sand, and silt.

Previous to the glacial invasion, the drainage systems were, in many localities, quite different from what they are now. Streams flowing northward in pre-glacial times became blocked by the ice front and their channels, in some cases, were entirely filled with drift. This caused a reversal of direction of flow in large river systems and forced streams to seek new outlets to the southward.

Thus the influence of the ice on drainage was felt for hundreds of miles beyond the southernmost point reached by it. The damming of rivers resulted in the formation of thousands of more or less permanent lakes, such as the Finger Lakes of New York, in which streams are constantly depositing sandy sediments.

With the final retreat of the ice from the Great Lakes region, drainage of that basin was again possible through the St. Lawrence Valley, and as a result numerous temporary lakes bordering on the ice margin disappeared. Sands and silts, marking beach lines of these ancient lakes, are very common in the Great Lakes region. Not only were lake margins favorable for the formation of molding sands during the glacial period, but similar deposits were also laid down along many river valleys.

It is true that we owe the great majority of molding sand deposits to assortment of the glacial drift by wind and water currents, but there are many valuable deposits far south of the ice margin and entirely out of the drainage systems flowing from drift-covered regions. Decay of certain kinds of rock gives a residuary soil which only needs re-working by water in order to furnish sands useful for molding purposes. The direct product of the decay of the finer-grained feldspathic sandstones may be excellent for molding.

II. Properties of Minerals.

Methods of Examination.

The microscopic investigation of the sands was done in the geological laboratory of Columbia University. An E. Leitz petrographic microscope was used. The apparatus also included a glass vessel for specific gravity separation and an outfit for microchemical tests. Polarized light was used in order to distinguish many minerals through their crystal fragments. Ordinary light gives the necessary information in regard to shape of grain, purity of quartz and cementing materials. For the separation of heavy minerals from those of low specific gravity, the Thoulet solution was found useful. This is a mixture of mercuric iodide and potassium iodide, and has a specific gravity of about 3.15 when the solution is saturated. Minerals can thus be separated and isolated for the application of special tests.

Description of Minerals.

Minerals recognized in the molding sands

Quartz		Rutile
		Garnet
	Orthoclase	Corundum
Feldspar	Microcline	Magnetite
	Plagioclase	Chlorite
		Serpentine
	Tremolite	Hematite
Amphibole	Actinolite	Limonite
	Hornblende	Pyrite
		Kaolinite
	Diopside	Pyrophyllite
	Enstatite	Sillimanite
Pyroxene	Hypersthene	Andalusite
	Augite	Cyanite
		Spinel
	Muscovite	Calcite
Mica	Sericite	Dolomite
	Biotite	Siderite
		Monazite
Tourmaline		Titanite
Zircon		Epidote
Apatite		

Quartz.—Composition SiO_2. One of the most abundant minerals in nature. Its hardness, insolubility, and lack of cleavage render quartz almost indestructible, and hence it is the main constituent of sand and gravel, the amount of quartz in molding sands usually ranging from 50 to 70 per cent. The principal source of quartz is granite and other igneous and metamorphic rocks, in the formation of which quartz is the last constituent to crystallize during the cooling, hence contains inclusions of minerals that solidified earlier. Hair-like rutile crystals, rods of apatite, and dust particles of other minerals are common and can readily be seen under the microscope. Liquid and gas inclusions are especially characteristic of quartz, and these may be water, carbonic acid, or both.

Feldspar.—Orthoclase, a potash aluminum silicate. Microcline, composition same as orthoclase but crystallized differently. Plagioclase, a soda, lime, or soda-lime aluminum silicate.

Feldspars are probably next to quartz in abundance and distribution in molding sands. They have a prominent cleavage in two directions inclined at or near 90°. Pink, gray, and white are common colors. In sands, grains are often seen that are made up of alternating layers of orthoclase and plagioclase to which the name microperthite is applied. Feldspars exposed to weathering in a moist climate undergo decomposition. The potash, soda, and lime bases may be leached out leaving kaolinite, a hydrated aluminum

silicate which is the essential constituent of clay. Another common alteration product is sericite.

Amphibole.—Composition variable. Hornblende, actinolite, and tremolite are the common varieties. They are silicates of magnesium, iron, aluminum, and lime. Hornblende has the most iron and is nearly black in color, while tremolite having no iron in its composition, is white. There is a prominent cleavage which is often fibrous. Fusion is not difficult, hence molding sands with much of these minerals are not good for heavy casting work. Only recent deposits derived from the glacial drift have amphibole in any amount as it is ordinarily altered to chlorite and other secondary products in the older sands.

Pyroxene.—Diopside, augite, enstatite, and hypersthene are the common varieties of pyroxene. Diopside is a silicate of lime and magnesia. Augite has lime and alumina in addition. Enstatite and hypersthene are silicates of magnesium and iron. Pyroxene forms a series similar to amphibole in chemical composition. The pyroxene minerals are common in recent sands derived from the glacial drift. The fusion being about like that of amphibole, these minerals are not desirable in sands to be used for heavy casting work.

Mica.—Muscovite and sericite are the common varieties of mica found in sands. They are hydrated potash, aluminum silicates. Both are resistant to decomposition on weathering. Sericite has a scaly appearance when viewed with microscope and is derived by the alteration of feldspar. Biotite, the black mica, is rare in sands as it alters readily to chlorite and limonite on weathering. Micas tend to lower the refractory quality of molding sands, hence are not advantageous.

Tourmaline.—A silicate of aluminum, lithium, manganese, lime, and magnesium. Color brown to black. Fuses easily, hence not good in molding sands. It is a common mineral in sands, and not being affected much by weathering, is found in deposits of all ages. Rod-like crystals as small as one five-thousandth of an inch are commonly seen under the microscope.

Zircon.—Composition, silicate of zirconia. Brown color, highly refractory, and therefore no detriment to quality of sand. Being one of the first minerals to crystallize on the cooling of molten rock, it is found as inclusions in feldspar and quartz.

Apatite.—A lime phosphate and fluoride. Fairly refractory. Is widely distributed in sands, though in minute quantities. Acting like zircon on cooling, it is very common as minute rod-like inclusions in feldspar and quartz.

Rutile.—Oxide of titanium. Color reddish-brown to nearly black. Refractory, hence no detriment in molding sands. Nearly every molding sand has quartz grains with hair-like inclusions of rutile.

Garnet.—The composition is variable. One variety is a silicate of lime and aluminum, another of lime and iron, and a third of magnesium and aluminum. Color pink, brown or nearly black. Fuses easily, and hence not desirable. Usually confined to sands from the glacial drift.

Corundum.—This is alumina. Hardness only exceeded by the diamond. Highly refractory. Occurs sparingly in sands. Comparatively stable, but alters to muscovite and spinel.

Magnetite.—Oxide of iron. Black color, and strongly attracted by magnet. Does not weather readily, but when acted upon by organic acids, decomposes to hematite and limonite. Common in beach sands and molding sands, and often found concentrated into placer deposits by wave action. Always present in recent sands, either as free grains or as inclusions in other minerals.

Chlorite.—A greenish mineral containing magnesium, iron, aluminum, silica, and water. Usually derived by the alteration of mica, pyroxene, and amphibole.

Serpentine.—A hydrated magnesium silicate. Is found in molding sands as microscopic yellowish flakes.

Hematite and Limonite.—Iron oxides, the latter hydrated. Highly refractory. Present in molding sands as earthy red or rusty brown masses. Surface waters charged with organic acids readily dissolve iron. As these waters percolate downward the iron is precipitated as a hydrated oxide between the sand grains. For this reason the grains of most molding sands are thickly coated with limonite.

Pyrite.—Pyrite is a sulphide of iron. It has a brassy metallic appearance and commonly crystallizes in cubes. When slightly heated a part of the sulphur is oxidized. Pyrite is not common in molding sands derived from surface deposits, but is very frequently present in deeper workings of quarries.

Kaolinite and Pyrophyllite.—Hydrated silicates of alumina. Kaolinite is an alteration product derived through the decomposition of feldspars. On weathering the feldspars in sands change to kaolinite and if the proportions are right, a good molding sand may result. Clay is impure kaolinite usually containing more or less quartz and iron oxide. Pure kaolinite is highly refractory. Pyrophyllite is a foliated or fibrous mineral, white colored, and having a greasy feel. It resembles kaolinite in composition and is likewise refractory.

Sillimanite, Andalusite, and Cyanite.—These are all silicates of alumina. They are common in mica schists and are occasionally found in sands derived by the erosion of such rocks. All are highly refractory.

Calcite and Dolomite.—Calcite is a carbonate of lime. It is the essential constituent of limestone. Sometimes found in minute particles in molding sands derived from glacial drift. Dolomite is a carbonate of lime and magnesia.

Siderite.—This is a carbonate of iron. It is a common mineral in sandstones, but is less common in uncemented molding sand deposits.

Monazite.—A phosphate of the rare metals cerium, lanthanum, and didymium. Very refractory. Highly valuable commercially, and occurring very sparingly in most sands.

Titanite.—A silicate and titanate of lime. Easily fusible. Occasionally found in molding sands, but very sparingly.

Epidote.—A silicate of alumina, lime, and iron with water in chemical combination. Color, pistache green. Fuses easily. Common in molding sands as small granular particles. It is an alteration product of feldspars and ferromagnesian minerals.

Spinel.—Minerals of the spinel group are aluminates of magnesium, iron, chromium, and other elements. Very refractory and resistant to decomposition. Occasionally found in molding sands.

Significance of Color.

As has already been stated, quartz is by far the most abundant mineral in sands used for molding purposes, constituting in most cases 50 to 70 per cent of the content. Color is of importance as indicating the nature of the accessory minerals. The white molding sands may have in addition to quartz such minerals as feldspars, mica, calcite, dolomite, and kaolinite. The carbonates —calcite and dolomite—usually show a distinct cleavage and effervesce in hydrochloric acid. Mica has a flaky, silvery appearance and cleaves into thin flexible scales. The feldspars are almost always partially altered to kaolinite and appear as white, claylike lumps which can be easily ground to powder. Olive green or bluish-green coloring is usually due to the presence of ferromagnesian minerals and their alteration products, of which chlorite and serpentine, the hydrated magnesia silicates, are the most common. Their derivation is chiefly by the alteration of olivene, amphibole, pyroxene, epidote, and biotite. Rusty yellow, reddish-brown, and chocolate colors in sand are due to iron oxides which coat the quartz grains and fill the interspaces. The brownish tints are caused by limonite and the red by hematite. The presence of magnetite can be detected by passing a magnet through the sand.

Relation of Mineral Content to Chemical Analysis.

The oxides determined in a molding sand analysis, where some idea of the fluxing constituents is desired, are as follows: SiO_2, Al_2O_3, FeO, Fe_2O_3, CaO, MgO, Na_2O, K_2O, TiO_2, and H_2O. Other oxides, minute quantities of which are present, are also determined at times, some of which are P_2O_5, ZrO_2 and SO_3.

Silica, *SiO_2.*—Quartz is responsible for nearly all the silica in molding sands other than that from the clay portion. Albite, a mineral of the feldspar group, contains 68.68 per cent of SiO_2. Other feldspar minerals contribute a lesser amount.

Alumina, *Al_2O_3.*—This is derived mostly from the feldspars and their decomposition products, such as clay and sericite. The most basic mineral of the plagioclase group contains 36.72 per cent of Al_2O_3. Pyroxene, amphibole, and mica are a large source of alumina in some sands.

Iron Oxides, FeO, Fe_2O_3.—Ferrous and ferric iron are largely due to magnetite, hematite, limonite, and siderite. There is a small amount of iron in chlorite, epidote, and some varieties of amphibole and tourmaline.

Lime, CaO.—This enters into the makeup of a number of minerals, including calcite, dolomite, diopside, garnet, apatite, and some members of the plagioclase group of feldspars. Recent sands from the glacial drift are characterized by a high lime content.

Magnesia, MgO.—This is a constituent of dolomite, serpentine, chlorite, diopside, and actinolite.

Soda and Potash, Na_2O, K_2O.—These are derived from the more acid feldspars. Potash is also a constituent of muscovite and sericite. Recent sands derived from the glacial drift have much undecomposed feldspar and as a result are high in soda and potash.

Water, H_2O.—Hydrated minerals such as limonite, kaolinite, serpentine, chlorite, and muscovite have water in chemical combination which is given off on ignition.

Titanium Oxide, TiO_2.—This is a constituent of rutile, ilmenite, and titanite.

Phosphoric Acid, P_2O_5.—Apatite is the most common phosphate in rocks. Monazite is of importance in some sand.

Zirconia, ZrO_2.—Zircon is the zirconia-bearing mineral in sands.

Sulphur.—Pyrite is the most common sulphur-bearing mineral in sands. Certain sulphates are occasionally present.

Refractory Properties of Sands.

The refractoriness of a sand depends largely on its mineral content. In general it may be said that sands consisting of a complex aggregation of minerals are more readily fusible than those of simple mineral composition. The melting points of some of the more common rock-forming minerals are given in the following table.[1]

Zircon	1900° C.	Hematite	1300° C.
Spinel	1900° C.	Magnetite	1260° C.
Quartz[2]	1600° C.	Muscovite	1230° C.
Rutile	1560° C.	Orthoclase	1230° C.
Apatite	1550° C.	Titanite	1210° C.
Plagioclase (anorthite)	1532° C.	Garnet (grossularite)	1150° C.
Diopside	1375° C.		

[1] The values for quartz, orthoclase, plagioclase and diopside are taken from the results of Day, Allen and Wright, of the Geophysical Laboratory of the Carnegie Institution at Washington. The authorities for the fusing points of the other minerals are Doelter, Joly and Cussack, and Brun, whose results are given in J. H. L. Vogt's book on "Die Silikatschmelzlösungen."

[2] Quartz changes to tridymite at 800° C. and that mineral melts at about 1600°.

Quartz, the principal constituent in sands selected for molding purposes, is one of the more refractory minerals, melting at 1600°, but it does not follow that sand made up largely of quartz will require a temperature of 1600° for melting. The quartz may be taken into *solution* at a much lower temperature when heated along with a number of less refractory minerals. Granite fuses at a temperature of 1240°, though quartz is one of its principal constituents. It is evident that some factor aside from the melting points of the individual minerals controls the fusion point of mineral aggregates.

Of recent years we have come to regard molten rock as essentially a solution of mineral matter in mineral matter. When a molding sand is heated the easily fusible minerals becoming liquid, at once attack the more refractory ones, and as a result the melting point of the aggregate is lowered. A homely illustration of this principle is the lowering of the melting point of ice by the addition of salt. Another reason for considering molten rock as a solution is the fact that the minerals do not crystallize from the molten mass in the reversed order of their fusibility as determined for each mineral separately. For instance, in the cooling of a lava flow, apatite, magnetite, and zircon are among the earliest minerals to form. Then come the ferromagnesian minerals such as hornblende, actinolite, and biotite. The next to solidify are the feldspars, and last of all comes quartz. Obviously this is a reversal of the order which one would expect; quartz, one of the most refractory of all, remains in solution till the last, and magnetite, among the less refractory ones, crystallizes early in the series.

With the above principles in mind the following statements may be made: (1) No one can predict more than approximately the melting temperature of a sand by merely inspecting its mineral list. (2) The presence of easily fusible minerals is detrimental to a sand, especially if those minerals be basic fluxes which will react with the quartz to form slag products. (3) Before sweeping conclusions can be drawn as to the relation of the mineral content of a molding sand to its behavior when subjected to high temperature, more extensive investigations must be made; the sands of known mineral composition should again be examined microscopically subsequent to their use for molding purposes and then some generalizations will be possible.

III. Mineral Constituents of the Molding Sands Tested.

The minerals are listed in order of abundance, No. 1 being the most important and 2 the next and so on. Their order is determined by direct inspection of the mount and is only approximate, and more of a qualitative than quantitative nature. "Mineral dust" and "mineral flour" are descriptive terms for particles about .0002 of an inch in diameter and smaller. Such material is ordinarily spoken of as "clay," but the microscope shows that the composition of this portion is not greatly different from that of the coarser material. Limonite and kaolinite are in some cases the main constituents of this fine material, but quartz, tourmaline, sericite and many other minerals are also present.

The natural molding sands are designated from A-1 down to Z-1. The artificial molding sands are designated from AA-1 down to BB-6. As they are made up of only two sands and two clays, the mineral characteristics of these are given only. (See Memorandum on *Artificial Molding Sands* further on.)

Natural Molding Sands.

A-1

1. Quartz
2. Tourmaline
3. Zircon
4. Chlorite
5. Serpentine
6. Muscovite
7. Hornblende
8. Actinolite
9. Orthoclase
10. Limonite
11. Apatite
12. Tremolite
13. Garnet
14. Kaolinite
15. Magnetite

Nearly all passes through 100 mesh. A few grains are slightly over .008" diameter and grade down to about .0004". There is not much mineral dust. Only the largest grains show rounding. There is a moderate amount of limonite coating on the grains.

B-1

1. Quartz
2. Microcline
3. Limonite
4. Muscovite
5. Zircon
6. Tourmaline
7. Magnetite
8. Rutile

Largest grains about .016". Most grains larger than .004" are roughly rounded. There is a rather abundant limonite coating. The mineral dust is small in amount.

B-2

1. Quartz
2. Tourmaline
3. Zircon
4. Limonite
5. Magnetite
6. Muscovite
7. Chlorite
8. Apatite
9. Serpentine
10. Kaolinite
11. Calcite
12. Sericite
13. Rutile

The sand is well assorted. The largest particles are about .004" diameter and there is not much mineral flour. A few of the largest grains are slightly rounded. The limonite coating on the grains is moderate in amount.

B-3

1. Quartz
2. Plagioclase
3. Microcline
4. Orthoclase
5. Limonite
6. Hornblende
7. Diopside
8. Muscovite
9. Magnetite
10. Apatite
11. Kaolinite
12. Monazite
13. Rutile

The largest particles have a diameter of about .024". All grains larger than .004" rounded. Limonite coating on grains average. Magnetite more abundant than usual. Feldspars abundant and show little signs of decomposition.

B-4

1. Quartz
2. Zircon
3. Plagioclase
4. Tourmaline
5. Muscovite
6. Magnetite
7. Serpentine
8. Limonite
9. Chlorite
10. Kaolinite

The sand is made up of sharp, well-assorted grains, the largest of which are barely .006" diameter. There is very little mineral flour. The limonite content is below average. Feldspars show little alteration.

B-5

1. Quartz
2. Calcite
3. Plagioclase
4. Microcline
5. Tourmaline
6. Zircon
7. Chlorite
8. Garnet
9. Serpentine
10. Hornblende
11. Magnetite
12. Rutile
13. Muscovite
14. Apatite
15. Kaolinite

There are few grains as large as .006″. Rounding due to travel is noticeable in some only .0032″ diameter. The feldspars are unaltered. Calcite is probably equal to the sum of all other accessory minerals.

B-6

1. Quartz
2. Limonite
3. Zircon
4. Tourmaline
5. Apatite
6. Magnetite
7. Sericite
8. Rutile

The largest grains are about .02″ diameter. Rounding of the grains is not well developed. The limonite coating is above average.

B-7

1. Quartz
2. Zircon
3. Tourmaline
4. Muscovite
5. Limonite
6. Microcline
7. Magnetite
8. Chlorite
9. Calcite
10. Apatite
11. Rutile

A well-assorted sand. The largest grains are only .0052″ diameter and there is not much mineral dust. Limonite coating of grains average.

B-8

1. Quartz
2. Tourmaline
3. Zircon
4. Serpentine
5. Magnetite
6. Limonite
7. Muscovite
8. Plagioclase
9. Garnet
10. Apatite
11. Rutile
12. Kaolinite

A well-assorted sand. Largest grains about .006″ diameter and few show any rounding. There is more mineral dust than usual. Limonite content below average.

C-1

1. Quartz
2. Limonite
3. Tourmaline
4. Zircon
5. Magnetite
6. Serpentine
7. Microcline
8. Apatite

There are few grains larger than .004″ and none show rounded edges due to travel. The limonite content is average.

C-2

1. Quartz	6. Magnetite
2. Limonite	7. Apatite
3. Tourmaline	8. Muscovite
4. Zircon	9. Corundum
5. Serpentine	

Largest grains about .012", grading thence down to mineral flour. Most of the larger grains are slightly travel rounded. The limonite coating is average.

C-3

1. Quartz	6. Orthoclase
2. Limonite	7. Kaolinite
3. Zircon	8. Sericite
4. Microcline	9. Monazite
5. Magnetite	10. Rutile

There are a few grains .024" diameter. All larger than .004" are roughly rounded. There is more limonite coating than usual.

C-4

1. Quartz	6. Actinolite
2. Limonite	7. Muscovite
3. Zircon	8. Apatite
4. Tourmaline	9. Magnetite
5. Microcline	10 Rutile

A well-assorted sand with the largest particles having a diameter of .024" and little mineral dust. The larger grains are roughly rounded. Most of the magnetite is included in quartz. There is more limonite than usual.

C-5

1. Quartz	6. Magnetite
2. Limonite	7. Actinolite
3. Zircon	8. Apatite
4. Tourmaline	9. Chlorite
5. Microcline	10. Rutile

A rather coarse sand with some grains slightly larger than .04" diameter. The larger grains are roughly rounded. There is an average limonite content.

C-6

1. Quartz	6. Microcline
2. Limonite	7. Magnetite
3. Actinolite	8. Apatite
4. Zircon	9. Rutile
5. Tourmaline	

Diameter of largest grains .028". Rounding evident in grains .004" diameter and larger. Limonite content average.

D-1

1. Quartz
2. Garnet
3. Hornblende
4. Diopside
5. Microcline
6. Plagioclase
7. Orthoclase
8. Zircon
9. Magnetite
10. Limonite
11. Serpentine
12. Tourmaline
13. Apatite
14. Kaolinite
15. Sericite

Well-assorted sand. Largest grains .008″ diameter and not much mineral dust. Grains larger than .0072″ show rounding due to travel. Limonite below average.

D-2

1. Quartz
2. Diopside
3. Garnet
4. Hornblende
5. Plagioclase
6. Orthoclase
7. Microcline
8. Limonite
9. Zircon
10. Magnetite
11. Tourmaline
12. Sericite
13. Apatite
14. Serpentine
15. Kaolinite
16. Hematite
17. Rutile

Largest grains .028″ diameter. Both well-rounded and sharp grains are common. Limonite content average. Microperthite, an intergrowth of orthoclase and albite (one of the plagioclases), is common. None of the feldspars show much alteration.

D-3

1. Quartz
2. Garnet
3. Diopside
4. Hornblende
5. Orthoclase
6. Plagioclase
7. Microcline
8. Enstatite
9. Limonite
10. Hypersthene
11. Zircon
12. Magnetite
13. Chlorite
14. Kaolinite
15. Serpentine
16. Sericite
17. Biotite
18. Hematite
19. Sillimanite
20. Rutile

Largest grains .032″ diameter. Grains as small as .004″ are more or less travel rounded. The limonite content is average in amount. Microperthite, an intergrowth of orthoclase and plagioclase, is common. The magnetite is present as free grains and as inclusions in quartz.

E-1

1. Quartz	10. Actinolite
2. Hornblende	11. Limonite
3. Garnet	12. Zircon
4. Hypersthene	13. Magnetite
5. Diopside	14. Kaolinite
6. Enstatite	15. Serpentine
7. Plagioclase	16. Chlorite
8. Orthoclase	17. Apatite
9. Microcline	18. Rutile

Largest grains .024″ diameter. Not much mineral dust. The degree of rounding is variable; there are sharp and nearly spherical grains. The limonite content is slightly above average. A few microperthite grains were noticed. Feldspars are only slightly decomposed.

F-1

1. Quartz	10. Magnetite
2. Garnet	11. Serpentine
3. Hornblende	12. Zircon
4. Enstatite	13. Chlorite
5. Plagioclase	14. Kaolinite
6. Diopside	15. Sericite
7. Microcline	16. Titanite
8. Orthoclase	17. Apatite
9. Limonite	18. Hematite

There are a few grains .024″ diameter. Mineral flour is abundant. Both angular and well-rounded grains are common. The limonite content is average. Plant fragments are present.

F-2

1. Quartz	10. Limonite
2. Garnet	11. Tourmaline
3. Enstatite	12. Kaolinite
4. Hornblende	13. Sericite
5. Microcline	14. Chlorite
6. Plagioclase	15. Magnetite
7. Orthoclase	16. Hematite
8. Tremolite	17. Apatite
9. Serpentine	18. Rutile

Practically all the sample passes through the 100-mesh sieve. The shape of grain varies from sharp to nearly spherical. Limonite content below average. Microperthite grains were seen. The quartz has more liquid and gas inclusions than usual.

F-3

1. Quartz	8. Hypersthene
2. Garnet	9. Magnetite
3. Orthoclase	10. Zircon
4. Plagioclase	11. Limonite
5. Microcline	12. Chlorite
6. Hornblende	13. Kaolinite
7. Enstatite	14. Sericite

Diameter of largest grains .024″. Some grains are well rounded. Limonite content average. Microperthite grains were noticed.

F-4

1. Quartz	9. Limonite
2. Garnet	10. Zircon
3. Orthoclase	11. Magnetite
4. Plagioclase	12. Serpentine
5. Diopside	13. Kaolinite
6. Enstatite	14. Sericite
7. Microcline	15. Apatite
8. Hornblende	16. Hematite

Largest grains .024″ diameter. Well-rounded and angular grains are common. Limonite content below average. The garnet varies in color from colorless to deep pink.

F-5

1. Quartz	10. Limonite
2. Hypersthene	11. Magnetite
3. Garnet	12. Apatite
4. Diopside	13. Kaolinite
5. Plagioclase	14. Titanite
6. Orthoclase	15. Epidote
7. Microcline	16. Hematite
8. Hornblende	17. Rutile
9. Enstatite	

Largest grains .032″ diameter. Some are nearly spherical in shape, while others are angular. The limonite content is average. Microperthite grains are common. Magnetite, apatite and rutile are mostly inclusions in quartz.

F-6

1. Quartz	6. Plagioclase
2. Garnet	7. Enstatite
3. Diopside	8. Zircon
4. Hypersthene	9. Limonite
5. Orthoclase	10. Hornblende

11. Microcline
12. Magnetite
13. Kaolinite
14. Sericite
15. Chlorite
16. Apatite
17. Rutile

Largest grains .032" diameter. The larger grains are nearly all travel rounded. Limonite content below average. Microperthite is present. Liquid and gas inclusions are abundant in the quartz. The feldspars show little alteration.

G-1

1. Quartz
2. Garnet
3. Diopside
4. Plagioclase
5. Hornblende
6. Microcline
7. Actinolite
8. Tourmaline
9. Zircon
10. Limonite
11. Serpentine
12. Kaolinite
13. Sericite

A very well-assorted sand, few grains larger than .006" and little mineral dust. All the grains are angular in shape. Limonite content low. Plant fragments present.

G-2

1. Quartz
2. Microcline
3. Garnet
4. Actinolite
5. Tremolite
6. Diopside
7. Plagioclase
8. Kaolinite
9. Zircon
10. Chlorite
11. Limonite
12. Magnetite
13. Sericite
14. Titanite
15. Apatite
16. Hematite
17. Sillimanite
18. Rutile

Diameter of largest grains .024"; most grains .004" and larger are well rounded. There is much mineral dust, which is largely quartz and kaolinite. The limonite content is low.

G-3

1. Quartz
2. Microcline
3. Actinolite
4. Enstatite
5. Hornblende
6. Plagioclase
7. Orthoclase
8. Zircon
9. Limonite
10. Kaolinite
11. Magnetite
12. Sericite
13. Tourmaline
14. Garnet
15. Muscovite
16. Apatite
17. Rutile
18. Hematite

Largest grains .028″ diameter, subspherical to angular in shape. Limonite content average. Feldspars are only slightly decomposed.

G-4

1. Quartz
2. Microcline
3. Limonite
4. Garnet
5. Orthoclase
6. Plagioclase
7. Zircon
8. Muscovite
9. Diopside
10. Actinolite
11. Kaolinite
12. Sericite
13. Magnetite
14. Epidote
15. Apatite
16. Rutile

Largest grains .024″ diameter. Most grains are angular in shape. There is more limonite than usual. Microperthite was seen.

G-5

1. Quartz
2. Limonite
3. Microcline
4. Actinolite
5. Hornblende
6. Orthoclase
7. Kaolinite
8. Sericite
9. Rutile
10. Andalusite

Largest grains .036″ diameter. Travel-rounded grains abundant; some angular ones also present. Limonite coating above average.

G-6

1. Quartz
2. Calcite
3. Actinolite
4. Zircon
5. Garnet
6. Enstatite
7. Plagioclase
8. Magnetite
9. Limonite
10. Apatite
11. Sericite
12. Kaolinite
13. Hematite

A very well-assorted sand with few grains larger than .0048″ and very little mineral dust. Limonite content low. Plant fragments present.

G-7

1. Quartz
2. Limonite
3. Plagioclase
4. Orthoclase
5. Actinolite
6. Zircon
7. Garnet
8. Kaolinite
9. Sericite
10. Chlorite
11. Magnetite
12. Apatite
13. Rutile

Largest grains .004″ diameter. The larger grains are roughly rounded. Much limonite coating.

G-8

1. Quartz
2. Calcite
3. Feldspars
4. Garnet
5. Limonite
6. Diopside
7. Tremolite
8. Zircon
9. Muscovite
10. Magnetite
11. Tourmaline
12. Serpentine

A well-assorted sand with an average diameter of about .0024". Very little mineral dust. Limonite content below average.

H-1

1. Quartz
2. Limonite
3. Plagioclase
4. Microcline
5. Tourmaline
6. Zircon
7. Kaolinite
8. Sericite
9. Muscovite
10. Serpentine
11. Magnetite
12. Apatite
13. Rutile

Largest grains .028" diameter. Most of the larger grains are rounded; some are nearly spherical. Grains only .0024" diameter show some rounding. Limonite content average. Feldspars are somewhat altered.

H-2

1. Quartz
2. Microcline
3. Orthoclase
4. Plagioclase
5. Tourmaline
6. Limonite
7. Muscovite
8. Kaolinite
9. Sericite
10. Magnetite
11. Zircon
12. Rutile

Largest grains .006" diameter. Shape of grains, subspherical to angular. Grains slightly smaller than .004" show rounding. Limonite content below average. Microperthite grains seen.

H-3

1. Quartz
2. Limonite
3. Microcline
4. Orthoclase
5. Actinolite
6. Kaolinite
7. Sericite
8. Zircon
9. Muscovite
10. Magnetite
11. Rutile

Largest grains .02" diameter. Nearly all of the large grains show travel rounding. Mineral dust rather abundant. Limonite content average.

H-4

1. Quartz
2. Limonite
3. Microcline
4. Actinolite
5. Kaolinite
6. Sericite
7. Apatite
8. Rutile

Largest grains .028" diameter. Grains larger than .004" show rounding due to travel. Mineral dust is rather abundant. Limonite content average.

K-1

1. Quartz
2. Garnet
3. Actinolite
4. Diopside
5. Hornblende
6. Enstatite
7. Microcline
8. Tourmaline
9. Orthoclase
10. Plagioclase
11. Limonite
12. Zircon
13. Magnetite
14. Kaolinite
15. Sericite
16. Apatite
17. Titanite
18. Rutile
19. Chlorite

A well-assorted sand. Diameter of largest grains about .016". Mineral dust rather abundant. The larger grains are more or less rounded. Limonite content slightly below average. Microperthite grains were seen.

L-1

1. Quartz
2. Garnet
3. Microcline
4. Enstatite
5. Diopside
6. Zircon
7. Hornblende
8. Titanite
9. Limonite
10. Tourmaline
11. Magnetite
12. Kaolinite
13. Sericite
14. Apatite
15. Hematite
16. Rutile

Largest grains .024" diameter. There are few grains smaller than .006". Those above .004" are slightly rounded. Limonite content less than average. Microperthite grains present.

L-2

1. Quartz
2. Garnet
3. Enstatite
4. Orthoclase
5. Plagioclase
6. Microcline
7. Limonite
8. Zircon
9. Kaolinite
10. Sericite

Coarse gravelly sand. Average diameter of grain about .04". Most particles are well rounded. Limonite content average. Microperthite is present.

L-3

1. Quartz	8. Actinolite
2. Garnet	9. Epidote
3. Microcline	10. Magnetite
4. Enstatite	11. Chlorite
5. Orthoclase	12. Apatite
6. Plagioclase	13. Rutile
7. Zircon	14. Hematite

A rather coarse sand. Largest grains .06" diameter. Most of the grains are angular in shape. Limonite content average. Microperthite grains were seen.

L-4

1. Quartz	8. Microcline
2. Garnet	9. Diopside
3. Hypersthene	10. Limonite
4. Orthoclase	11. Zircon
5. Plagioclase	12. Magnetite
6. Enstatite	13. Apatite
7. Hornblende	14. Hematite

Largest grains about .04" diameter. Most grains larger than .004" are roughly rounded. Little mineral dust. Limonite content average. Microperthite was seen. Plant fragments are present.

L-5

1. Quartz	9. Limonite
2. Garnet	10. Tremolite
3. Hornblende	11. Kaolinite
4. Enstatite	12. Sericite
5. Orthoclase	13. Chlorite
6. Plagioclase	14. Rutile
7. Microcline	15. Apatite
8. Zircon	16. Hematite

There are few fragments larger than .006". The larger ones are nearly spherical in shape. Limonite content average. Microperthite grains and plant fragments were seen.

L-6

1. Quartz	6. Hornblende
2. Orthoclase	7. Enstatite
3. Plagioclase	8. Limonite
4. Garnet	9. Magnetite
5. Microcline	10. Sericite

11. Kaolinite
12. Chlorite
13. Hematite
14. Epidote
15. Tourmaline
16. Apatite
17. Rutile

Largest grains .028" diameter. The larger ones are roughly rounded. Mineral dust abundant. Limonite content average. Microperthite is common.

L-7

1. Quartz
2. Garnet
3. Orthoclase
4. Plagioclase
5. Microcline
6. Diopside
7. Enstatite
8. Limonite
9. Zircon
10. Chlorite
11. Magnetite
12. Sericite
13. Kaolinite
14. Rutile
15. Hematite

Largest grains .024" diameter. Both angular and well-rounded grains are common. Limonite content below average. There is little microperthite.

L-8

1. Quartz
2. Garnet
3. Diopside
4. Enstatite
5. Orthoclase
6. Plagioclase
7. Hornblende
8. Microcline
9. Limonite
10. Kaolinite
11. Sericite
12. Actinolite
13. Epidote
14. Magnetite
15. Chlorite
16. Zircon
17. Tourmaline
18. Cyanite
19. Rutile
20. Hematite

Diameter of largest grains .032". Roughly rounded fragments most common. Mineral dust average. Limonite content average. Microperthite is common.

L-9

1. Quartz
2. Garnet
3. Orthoclase
4. Plagioclase
5. Microcline
6. Hypersthene
7. Hornblende
8. Enstatite
9. Sericite
10. Kaolinite
11. Chlorite
12. Zircon
13. Tourmaline
14. Apatite
15. Hematite
16. Rutile

Largest grains .028″ diameter. Well-rounded grains are common. Mineral dust more abundant than usual. Limonite content average. There is a little microperthite.

L-10

1. Quartz
2. Orthoclase
3. Plagioclase
4. Garnet
5. Limonite
6. Enstatite
7. Hornblende
8. Zircon
9. Magnetite
10. Chlorite
11. Sericite
12. Kaolinite
13. Epidote
14. Rutile
15. Hematite

A rather coarse, poorly assorted sand. Many grains are .04″ diameter and occasional ones are .02″. Shape of grain varies from angular to nearly spherical. Mineral dust abundant. Limonite content more than average. Microperthite is present.

M-1

1. Quartz
2. Orthoclase
3. Plagioclase
4. Garnet
5. Hypersthene
6. Enstatite
7. Hornblende
8. Diopside
9. Limonite
10. Sericite
11. Kaolinite
12. Tourmaline
13. Zircon
14. Rutile
15. Chlorite
16. Titanite
17. Hematite

Largest grains .024″ diameter. Many of the grains are nearly spherical in shape. Mineral dust below average. Limonite content less than average. Microperthite grains considerably decomposed are present.

M-2

1. Quartz
2. Orthoclase
3. Plagioclase
4. Garnet
5. Hypersthene
6. Diopside
7. Kaolinite
8. Sericite
9. Limonite
10. Tourmaline
11. Zircon
12. Magnetite
13. Rutile
14. Hematite

Diameter of largest grains .024″. Rounding quite thorough in most grains. Mineral dust more abundant than usual. Limonite content below average. Microperthite and feldspars show considerable kaolinization.

M-3

1. Quartz
2. Garnet
3. Hornblende
4. Hypersthene
5. Plagioclase
6. Microcline
7. Orthoclase
8. Tourmaline
9. Kaolinite
10. Limonite
11. Magnetite
12. Zircon
13. Chlorite
14. Epidote
15. Apatite
16. Sillimanite
17. Rutile
18. Hematite

Largest grains .02" diameter. Rounding is noticeable in all grains down to a diameter of about .004". Mineral dust average. Limonite content average. Feldspars show kaolinization. The sillimanite is included in quartz.

M-4

1. Quartz
2. Hypersthene
3. Garnet
4. Enstatite
5. Hornblende
6. Orthoclase
7. Plagioclase
8. Limonite
9. Magnetite
10. Kaolinite
11. Zircon
12. Tremolite
13. Chlorite
14. Serpentine
15. Sericite
16. Hematite
17. Rutile

Both rounded and sharp angular grains are common. Mineral dust and limonite content average. There is a little microperthite and some plant fragments.

M-5

1. Quartz
2. Garnet
3. Hornblende
4. Hypersthene
5. Plagioclase
6. Limonite
7. Diopside
8. Tourmaline
9. Microcline
10. Kaolinite
11. Zircon
12. Magnetite
13. Chlorite
14. Sericite
15. Rutile

Largest grains .02" diameter. Most of the larger grains are well rounded. Mineral dust and limonite content average.

N-1

1. Quartz
2. Limonite
3. Kaolinite
4. Magnetite
5. Sericite
6. Zircon
7. Apatite
8. Rutile
9. Monazite
10. Spinel

Largest grains about .036" diameter. Well-rounded grains are common. Limonite coating abundant. A greenish octahedral crystal of spinel was seen included in quartz.

N-2

1. Quartz
2. Orthoclase
3. Hornblende
4. Actinolite
5. Plagioclase
6. Kaolinite
7. Sericite
8. Epidote
9. Tourmaline
10. Apatite
11. Sillimanite
12. Rutile

A rather coarse but well-assorted sand. There are occasional grains over .04" diameter. Limonite content average. The microperthite is much kaolinized. Liquid and gas inclusions are abundant in the quartz.

N-3

1. Quartz
2. Limonite
3. Kaolinite
4. Enstatite
5. Microcline
6. Tourmaline
7. Magnetite
8. Zircon
9. Augite
10. Hematite
11. Apatite
12. Rutile

Largest grains .024" diameter. Well-rounded grains are common. Mineral dust low and limonite content above average.

O-1

1. Quartz
2. Orthoclase
3. Plagioclase
4. Microcline
5. Garnet
6. Hornblende
7. Enstatite
8. Zircon
9. Titanite
10. Magnetite
11. Limonite
12. Kaolinite
13. Sericite
14. Serpentine
15. Chlorite
16. Hematite
17. Rutile

Largest grains .02" diameter. Most grains .004" diameter and larger are roughly rounded. Mineral flour average. Limonite content low. There is more microperthite than usual.

O-2

1. Quartz
2. Garnet
3. Hypersthene
4. Plagioclase
5. Orthoclase
6. Hornblende
7. Diopside
8. Enstatite
9. Limonite
10. Magnetite
11. Kaolinite
12. Sericite
13. Microcline
14. Epidote
15. Zircon
16. Muscovite
17. Rutile
18. Apatite
19. Hematite

Largest grains .028″ diameter. Both angular and well-rounded grains are common. Mineral dust average. Limonite coating less than average.

O-3

1. Quartz
2. Garnet
3. Orthoclase
4. Plagioclase
5. Hornblende
6. Limonite
7. Actinolite
8. Diopside
9. Magnetite
10. Kaolinite
11. Zircon
12. Chlorite
13. Rutile
14. Monazite

Assortment not very good; size of grain ranges from more than .04″ diameter down to mineral dust, which is abundant. Grains larger than .004″ usually show rounding. More limonite than usual. Microperthite and plant tissue are present.

O-4

1. Quartz
2. Orthoclase
3. Plagioclase
4. Enstatite
5. Limonite
6. Tourmaline
7. Magnetite
8. Zircon
9. Kaolinite
10. Sericite
11. Epidote
12. Muscovite
13. Chlorite
14. Rutile
15. Apatite

Largest grains about .032″ diameter. Grains larger than .004″ are crudely rounded. Limonite content average. Plant fragments quite common.

P-1

1. Quartz
2. Limonite
3. Magnetite
4. Muscovite
5. Tourmaline
6. Kaolinite
7. Chlorite

Diameter of largest grains .024". Shape angular to roughly rounded. Little mineral dust. Limonite content above average.

P-2

1. Quartz
2. Hornblende
3. Garnet
4. Limonite
5. Kaolinite
6. Microcline
7. Enstatite
8. Muscovite
9. Tourmaline
10. Sericite
11. Serpentine
12. Chlorite
13. Epidote
14. Apatite
15. Hematite

Largest grains .028" diameter. The sand is well assorted and there is little mineral dust. Limonite content average.

P-3

1. Quartz
2. Orthoclase
3. Plagioclase
4. Muscovite
5. Hornblende
6. Limonite
7. Enstatite
8. Tourmaline
9. Zircon
10. Sericite
11. Diopside
12. Serpentine
13. Epidote
14. Apatite
15. Hematite

Diameter of largest grains .024". The shape of grain varies from angular to roughly rounded. Little mineral dust and limonite content below average. Many of the feldspars show advanced kaolinization.

P-4

1. Quartz
2. Orthoclase
3. Plagioclase
4. Muscovite
5. Actinolite
6. Hornblende
7. Limonite
8. Tourmaline
9. Magnetite
10. Kaolinite
11. Sericite
12. Cyanite
13. Zircon
14. Apatite
15. Hematite
16. Rutile

Largest grains .02" diameter. Shape of grain angular to nearly spherical. Less mineral dust than usual. Limonite content average. Microperthite present.

P-5

1. Quartz
2. Tourmaline
3. Limonite
4. Muscovite
5. Kaolinite
6. Magnetite
7. Zircon
8. Epidote
9. Sericite

The sand is remarkably well assorted. There is little mineral dust and the largest grains are barely .004″ diameter. All grains are angular. Limonite content average.

R-1

1. Quartz
2. Limonite
3. Zircon
4. Tourmaline
5. Magnetite
6. Muscovite
7. Kaolinite
8. Sericite

There are a few grains .032″ diameter. Those larger than .004″ are crudely rounded. Limonite coating more than average.

S-1

1. Quartz
2. Garnet
3. Hornblende
4. Limonite
5. Orthoclase
6. Plagioclase
7. Enstatite
8. Diopside
9. Kaolinite
10. Sericite
11. Magnetite
12. Zircon
13. Chlorite
14. Rutile

There are a few grains .04″ diameter. Most grains larger than .004″ are well rounded. Mineral flour average. Limonite coating average. There is a small amount of microperthite.

T-1

1. Quartz
2. Limonite
3. Tourmaline
4. Magnetite
5. Feldspars
6. Muscovite
7. Garnet
8. Kaolinite
9. Actinolite
10. Sericite
11. Zircon

There are only a few grains larger than .004″. Mineral dust is not abundant. Angular grains predominate. Limonite content above average.

T-2

1. Quartz
2. Orthoclase
3. Plagioclase
4. Actinolite
5. Tourmaline
6. Limonite
7. Magnetite
8. Muscovite
9. Zircon
10. Kaolinite
11. Sericite

A very well-assorted sand. Little mineral dust and few grains larger than .004". The largest show slight rounding. Limonite less than usual.

U-1

1. Quartz
2. Feldspars
3. Zircon
4. Kaolinite
5. Limonite
6. Magnetite
7. Chlorite
8. Apatite
9. Rutile
10. Hematite

A poorly assorted, coarse, gravelly sand with some grains over .12" diameter. The shape of grain varies from angular to crudely rounded. Limonite coating average. Zircon inclusions in quartz were seen.

U-2

1. Quartz
2. Zircon
3. Tourmaline
4. Limonite
5. Magnetite
6. Feldspars
7. Hornblende
8. Apatite
9. Chlorite
10. Titanite
11. Cyanite
12. Spinel
13. Hematite
14. Rutile

A poorly assorted, coarse sand with some grains over .08" diameter. There is little mineral dust and an average amount of limonite. Liquid and gas inclusions are abundant in the quartz.

U-3

1. Quartz
2. Zircon
3. Limonite
4. Tourmaline
5. Microcline
6. Kaolinite
7. Magnetite
8. Sericite
9. Muscovite
10. Epidote
11. Apatite
12. Rutile

A coarse, poorly assorted sand. Some grains are .12" diameter. They are roughly rounded and have a moderate amount of limonite coating.

V-1

1. Quartz
2. Microcline
3. Limonite
4. Actinolite
5. Kaolinite
6. Sericite
7. Garnet
8. Hornblende
9. Magnetite
10. Epidote
11. Hematite
12. Rutile

Largest grains about .04" diameter. Nearly all .004" diameter and larger show rounded outlines. Limonite content average.

W-1

1. Quartz
2. Limonite
3. Tourmaline
4. Kaolinite
5. Magnetite
6. Zircon
7. Chlorite
8. Garnet
9. Sericite

Largest grains about .04" diameter. All larger than .004" are roughly rounded and have a limonite coating. Mineral dust more abundant than usual.

W-2

1. Quartz
2. Limonite
3. Tourmaline
4. Kaolinite
5. Zircon
6. Muscovite
7. Sericite
8. Hornblende
9. Rutile
10. Magnetite
11. Hematite

Largest grains .028" diameter. Shape angular to roughly rounded. Much limonite coating on the grains.

W-3

1. Quartz
2. Limonite
3. Kaolinite
4. Sericite
5. Zircon
6. Muscovite
7. Tourmaline
8. Microcline
9. Magnetite
10. Chlorite
11. Hematite

Diameter of largest grains .032". All grains .004" and larger are partially rounded and much coated with limonite. Mineral dust moderate.

W-4

1. Quartz
2. Limonite
3. Zircon
4. Kaolinite
5. Sericite
6. Muscovite
7. Tourmaline
8. Chlorite
9. Magnetite

Largest grains .028″ diameter. They are only slightly rounded and have a heavy limonite coat. There is little mineral dust.

X-1

1. Quartz
2. Limonite
3. Kaolinite
4. Sericite
5. Zircon
6. Hematite
7. Magnetite

Diameter of largest grains about .024″. Nearly all the larger grains are crudely rounded. Mineral dust less than usual. Limonite content above average. There is a little much altered microperthite.

Y-1

1. Quartz
2. Limonite
3. Zircon
4. Tourmaline
5. Kaolinite
6. Apatite
7. Rutile
8. Magnetite

A coarse, poorly assorted sand with pebbles .16″ diameter. Most of the grains are only slightly rounded. There is a heavy limonite coating.

Z-1

1. Quartz
2. Chlorite
3. Limonite
4. Zircon
5. Kaolinite
6. Sericite
7. Microcline
8. Tourmaline
9. Muscovite
10. Apatite
11. Cyanite
12. Rutile
13. Magnetite

A coarse sand with many grains over .08″ diameter. Angular and very well-rounded grains down to .004″ diameter are common. Tourmaline was found as an inclusion in quartz. The abundant black grains are chlorite.

Artificial Molding Sands.

(Memorandum prepared by the Secretary of the A. F. A.)

In preparing the artificial molding sands of this series of tests, there were selected for the silica portion two sands. The first was a very sharp, angular variety, running 98.61 per cent in silica, and with grains of uneven size. It is known as No. 588 of the Ohio Geological Survey set and comes from Zanesville, Ohio. The other sand is the very opposite in structure, being remarkably round and even grained, in fact the most perfect sand of this kind in the country. It is known as the Sylvania sand, and when washed is almost pure silica, making it highly desirable for glass-making. In the Geological Survey of Ohio list it is given as Nos. 594 and 595.

The bond of these artificial molding sands was obtained by adding clay. Two kinds were also used, the first, a fat ball clay from Woodbridge, New Jersey, stands about at the top of the list of clays in this country in this regard. The other clay is found about at the bottom of the list, and is an extremely lean china clay coming from Newark, Delaware.

In making up these molding sands the ones marked AA-1, 2, and 3, consist of the sharp sand with enough of the fat clay added to give 5 per cent, 10 per cent, and 15 per cent of the latter respectively. Similarly AA-4, 5, and 6 have this same sharp sand with 5 per cent, 10 per cent, and 15 per cent respectively of the lean clay in their composition. Next BB-1, 2, and 3 are made up of the round sand with the above mentioned proportions of fat clay; and BB-4, 5, and 6 the same round sand with like proportions of lean clay.

There is therefore a combination of a sharp sand with a fat clay, and with a lean clay, as well as a round sand with a fat, and a lean clay. Then each of these combinations has three separate percentages of the clays respectively in its make-up. In the physical tests, each of these sands is mixed with three percentages of water, and hence it makes an instructive series with which to work. The mineralogical characteristics of these two sands and the two clays are as given below:

Fat Ball Clay.

Pyrophyllite and kaolinite are the principal minerals. There is also considerable quartz, muscovite, and sericite. Plant fragments were noticed. There is a small amount of limonite present and the brownish color may be due to an impregnation of the clay by this mineral.

Lean China Clay.

Pyrophyllite and kaolinite are the chief constituents of this clay. A few small flakes of quartz were seen and also some muscovite and sericite.

Sharp Sand (No. 588 Ohio).

1. Quartz	6. Hematite
2. Zircon	7. Monazite
3. Tourmaline	8. Limonite
4. Microcline	9. Magnetite
5. Kaolinite	10. Epidote

Largest grains about .028" diameter, grading thence down to minute dust-like particles. Angular grains predominate. Zircon is more abundant than usual.

Round Sand (Nos. 594, 595 Ohio).

1. Quartz	4. Rutile
2. Calcite	5. Apatite
3. Dolomite	6. Limonite

Rounding to nearly spherical shape is characteristic of the sand grains. The cementing material is calcite and dolomite which occur as minute rhombohedrons in the interstices. Other accessory minerals are in extremely small amounts. The quartz is remarkably clean and has been slightly enlarged by secondary growth. Some of the calcite and dolomite is cemented to the quartz so would not be removed by washing.

Sea Sand from Perth Amboy, N. J.

As a matter of interest the mineralogical composition of sea sand is given. It was intended to make use of this for the round sand of the artificial molding sands. However, the table below shows that it is by no means as round as supposed, and moreover is so full of impurities—in the way of fluxing minerals— that its use would have been unwise in view of the excellent substitute available.

1. Quartz
2. Garnet
3. Muscovite
4. Enstatite
5. Actinolite
6. Hypersthene
7. Microcline
8. Plagioclase
9. Orthoclase
10. Zircon
11. Diopside
12. Magnetite
13. Chlorite
14. Apatite
15. Sericite
16. Kaolinite
17. Limonite
18. Hematite
19. Rutile

Largest grains about .032″ diameter. Particles smaller than .004″ are uncommon. Most of the grains are rather angular or only roughly rounded.

MOLDING SAND TESTS.

THE MICROSCOPE AS A TESTING MEDIUM FOR MOLDING SAND.

BY H. C. LOUDENBECK, WILMERDING, PA.

By presenting these photomicrographs of molding sand there will have been opened to foundrymen a further field of investigation and an additional method of testing molding sand. Just how valuable this will be to foundrymen in general remains to be seen, and will require further study. Detail information on the method of taking these photomicrographs is given herewith, as a stimulus to others who care to study the matter further. Some of the advantages of this method of testing will also be pointed out.

The sample of sand for microscopical examination should represent the lot or sand bank. The sampling is important and should be done carefully, for false conclusions can be made by this method of testing on account of not having a proper and representative sample. The sand should be thoroughly dry and should be disintegrated, but not crushed, *i. e.*, the individual grains should not be broken, but all lumps and conglomerates should be disintegrated and broken into the original grains. This can be done by breaking somewhat in a mortar and further by rubbing a small sample in the palm of the hand. A few grains should then be sprinkled on the glass slide, and these should be uniformly distributed so as not to give a heavy coat, or the individual grains will not be brought out distinct and clear. It is also advisable to examine different portions of the sample and obtain what seems to be an average field, as an abnormal view would be misleading. Always have in mind to obtain an average sample and an average view of that sample.

The apparatus used for making these photomicrographs consists of an ordinary metallurgical microscope fitted with an acromatic objective of 48 m. focus, and .08 numerical aperture, *i. e.*, a very low power objective. The stand is placed in a vertical

position and mounted with a photomicrograph camera, fitted for a 4″ x 5″ plate. The source of light consists of an arc light outfit with suitable condensers, cooling cell, etc. The same type as used

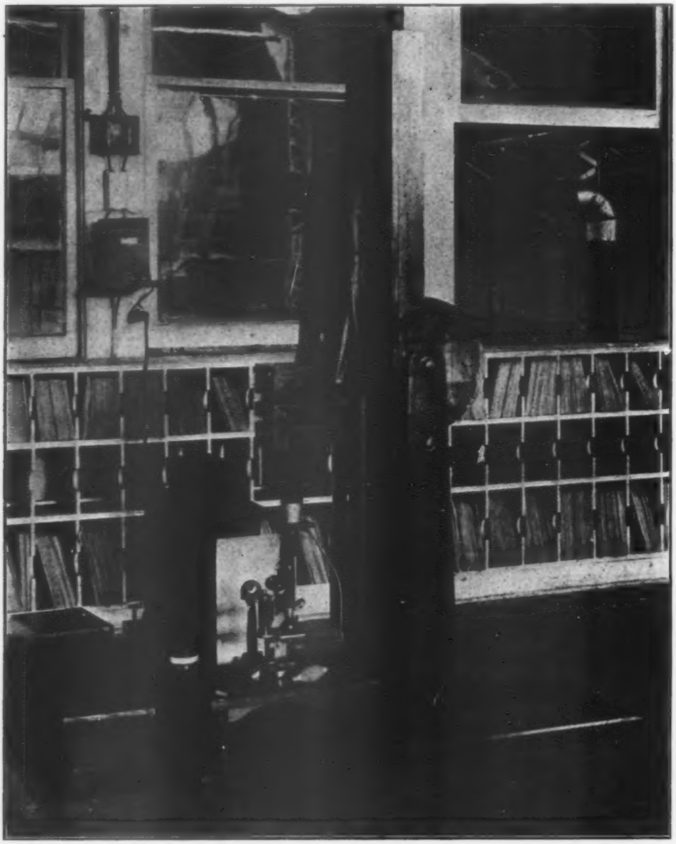


FIG. 1.

in metallurgical work would be satisfactory. The rays of light from this source are reflected downward by a Sorby-Beck reflector. This reflector was attached below the objective, and in this case,

where the magnification is low, this can readily be done. In all these photomicrographs the magnification was 18 diameters.*

Fig. 1 shows the apparatus in question.

The cost of this apparatus is not prohibitive, as it does not require the finest grade of microscopes or lenses. These photomicrographs were made with an ordinary microscope and ordinary lenses. The source of light is the most expensive, but if the matter were brought before the manufacturers of microscopical outfits an apparatus could be devised which would be reasonable in cost and would answer the purpose.

This method of testing should be especially valuable to producers of molding sand. A photomicrograph record of the sand in any particular mixture, stratum or sand bank, or shipment, could be made and this record filed with other information for future reference. It should also be of value where new sand banks are opened and a chart of the various strata and test holes could be made and the photomicrographs filed, to be referred to the same as the iron ore experts refer to test holes on iron ore property.

Special thanks are due to C. A. Kuhnert, photographer for the Westinghouse Air Brake Co., for his able assistance in taking the photomicrographs in question.

Photomicrographs of Molding Sands.

The following pages give the enlarged views of all the sands tested. Two illustrations are given of each sand, in order that a good conception might be had of its structure. The letter and number identifying each sand will be found below the respective illustrations. The Natural Molding Sands run from A-1 to Z-1, and the Artificial Molding Sands from AA-1 to BB-6.

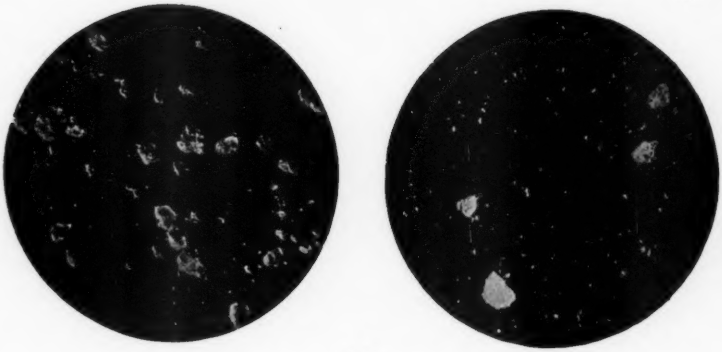
The discussion of the characteristics of these sands will be taken up after the physical and chemical tests have been published, so that the behavior of each sand under foundry conditions can be correlated with its composition, strength, and size and shape of grain.

*(Note by the Secretary.—In making the half-tones from the original photomicrographs—which were 3½" in diameter—a reduction to a 2" circle was necessary. Hence the enlargement of the sand grains to 18 diameters is reduced correspondingly.)

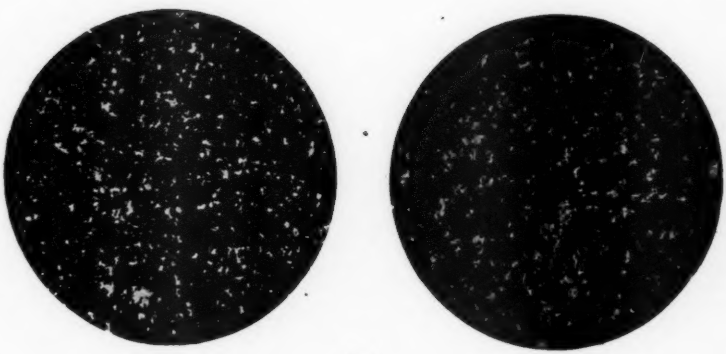
A–1

B–1

B–2
(40)

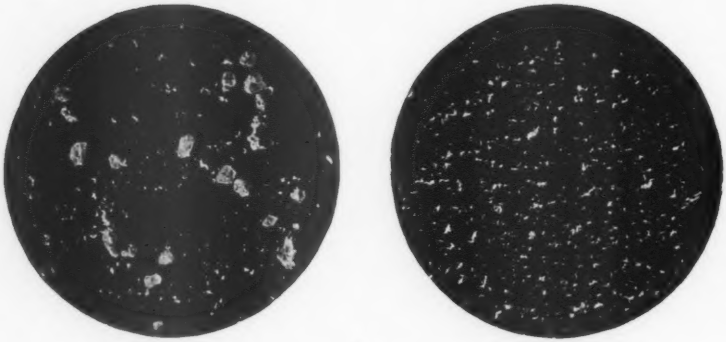


B-3

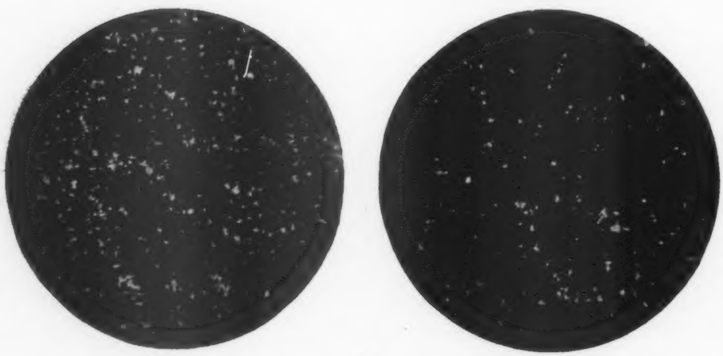


B-4

B-5
(41)



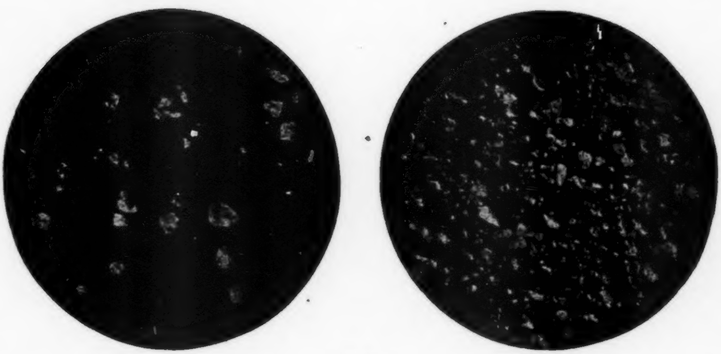
B–6



B–7

B–8
(42)

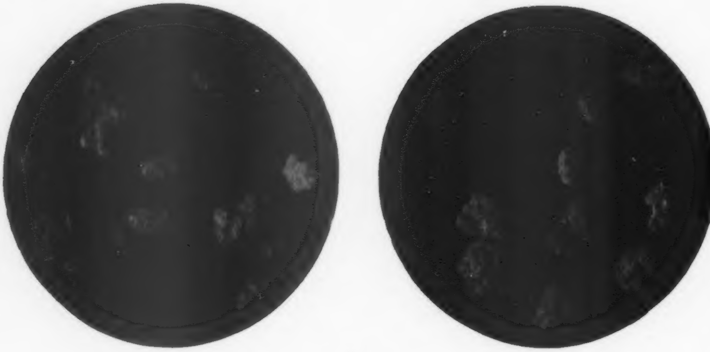
C–1



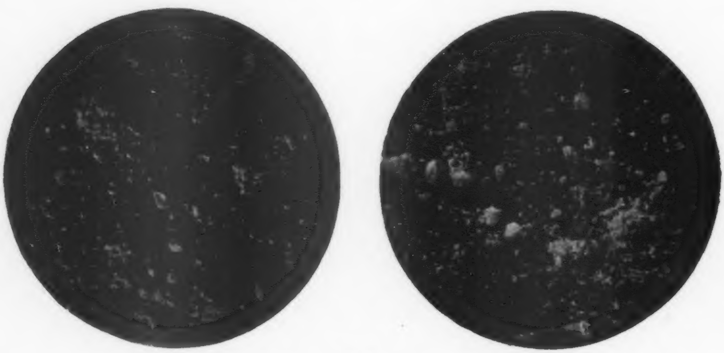
C–2

C–3

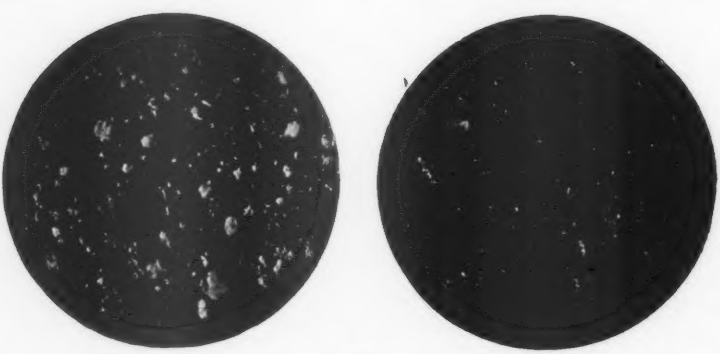
(43)



C–4



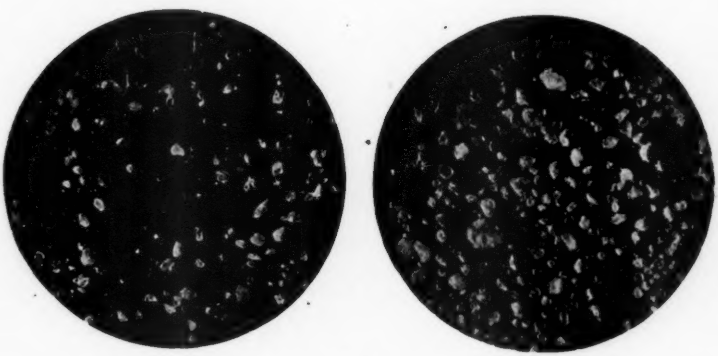
C–5



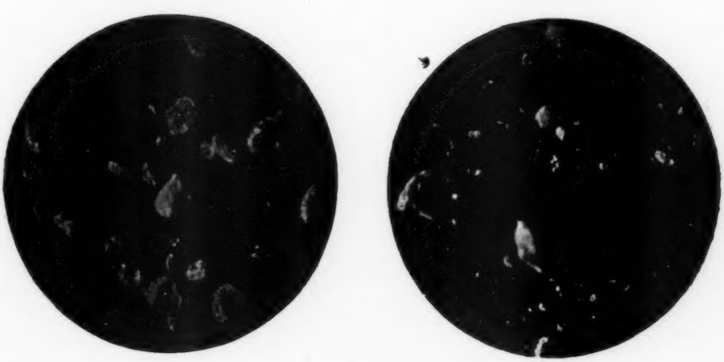
C–6

(44)

D–1

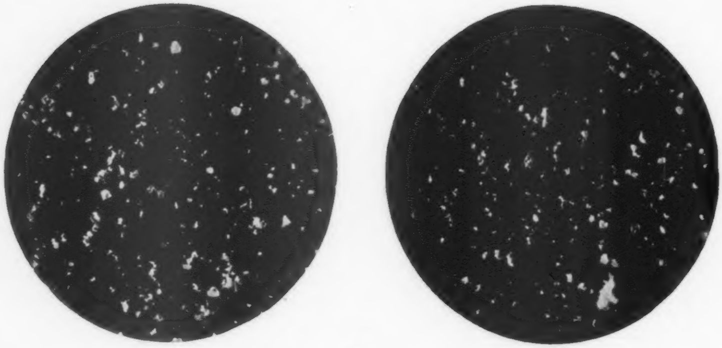


D–2

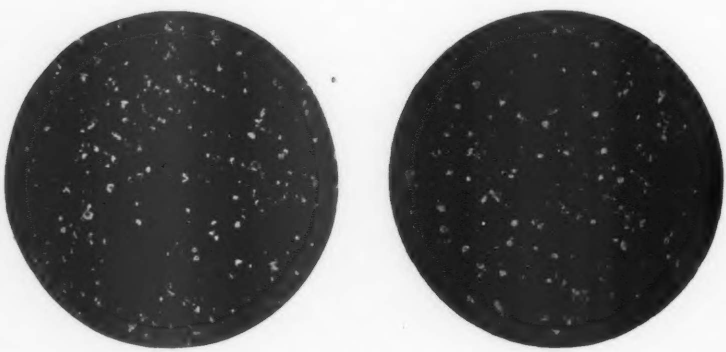


D–3

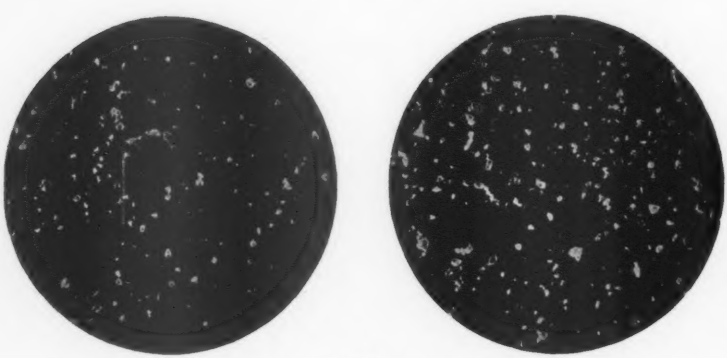
(45)



E–1

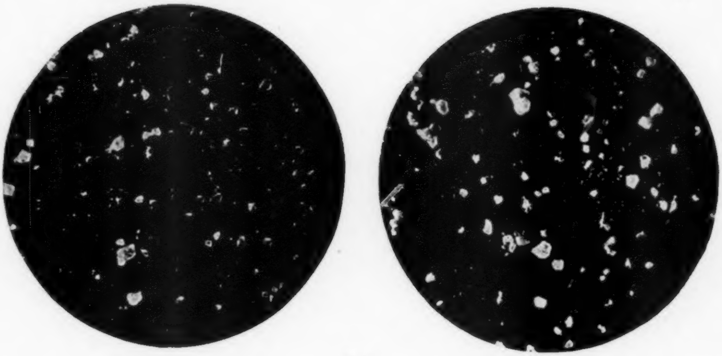


F–1

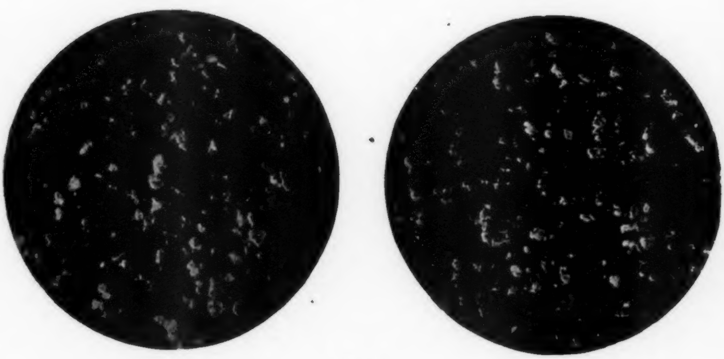


F–2

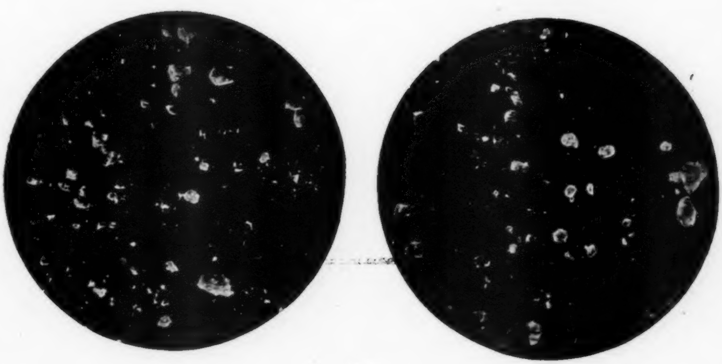
(46)



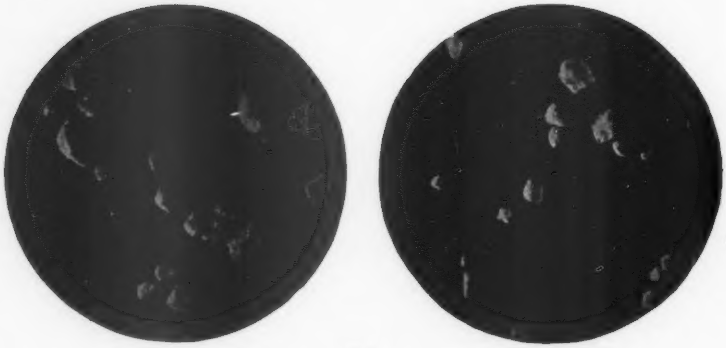
F-3



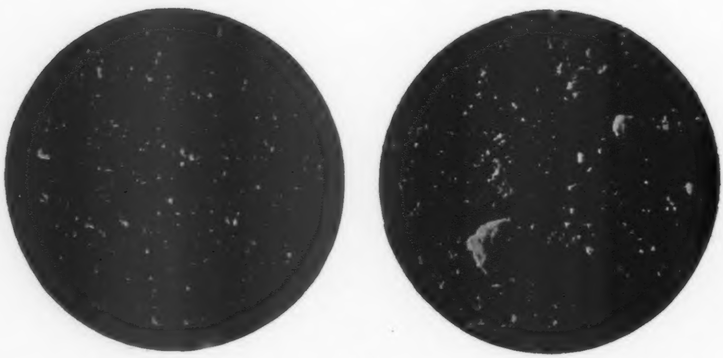
F-4



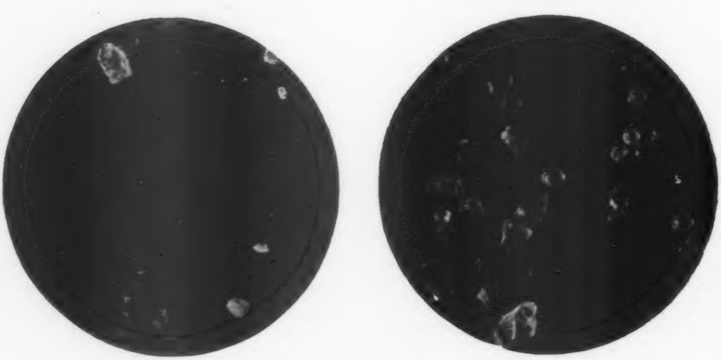
F-5
(47)



F–6

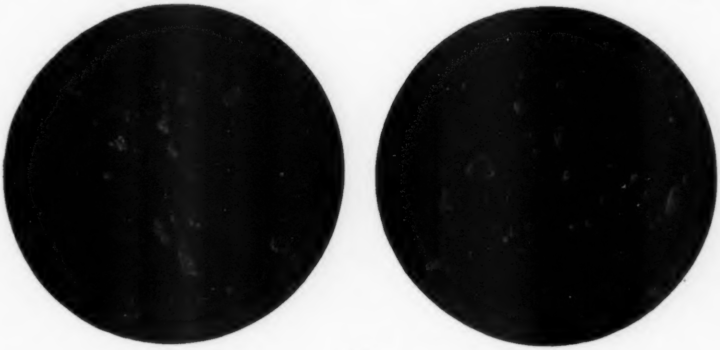


G–1

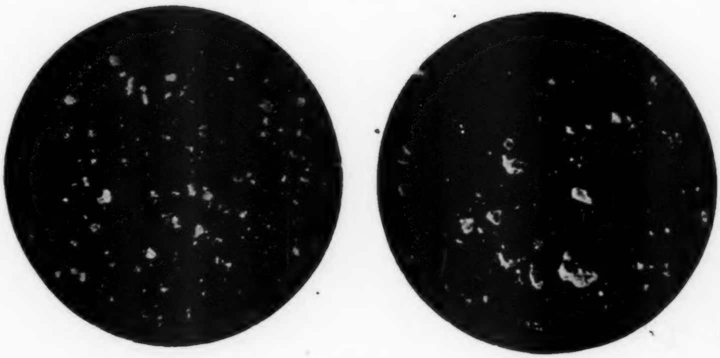


G–2

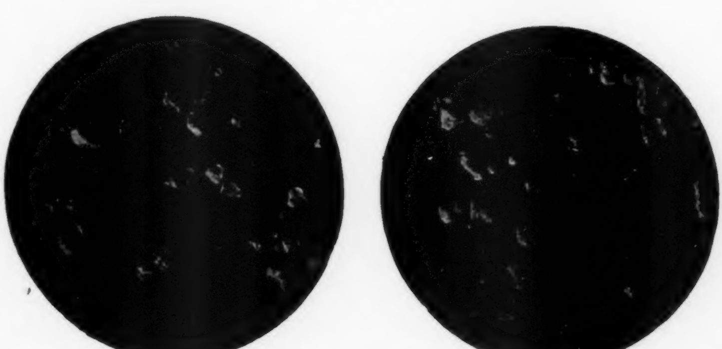
(48)



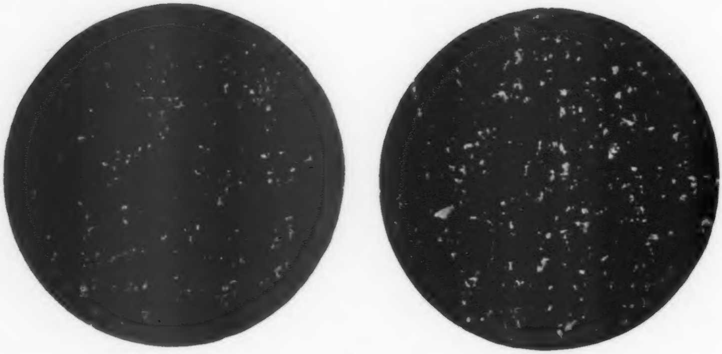
G–3



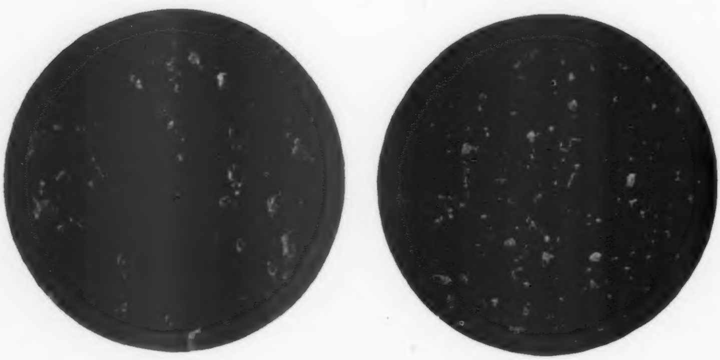
G–4



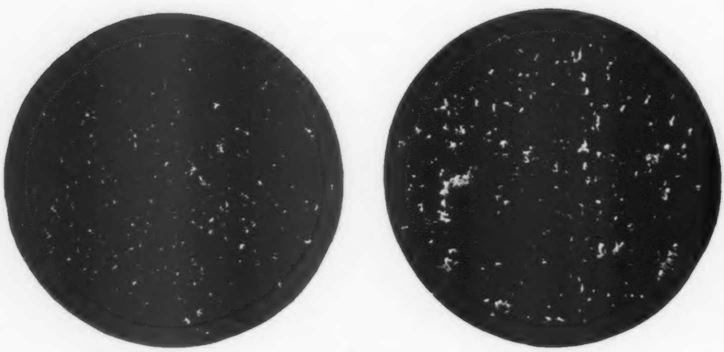
G–5
(49)



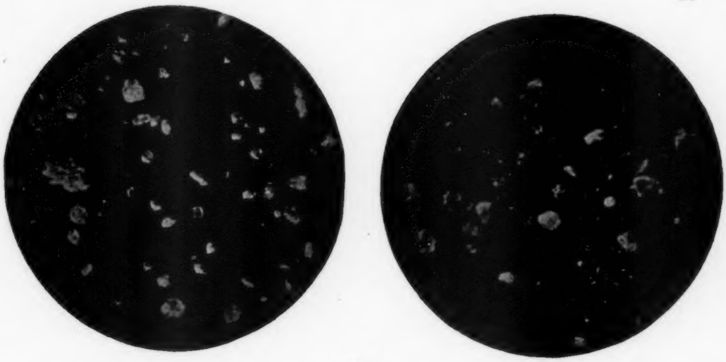
G–6



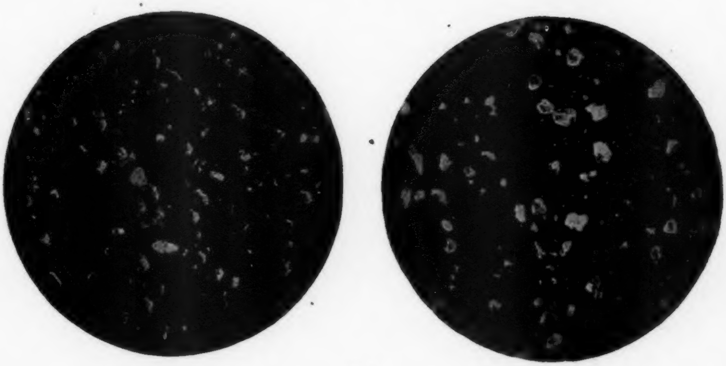
G–7



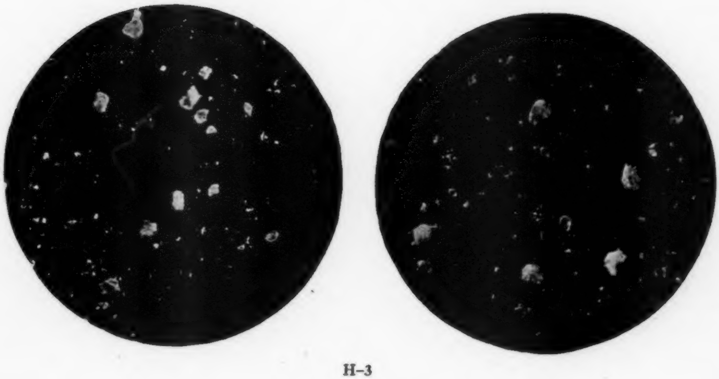
G–8
(50)



H–1

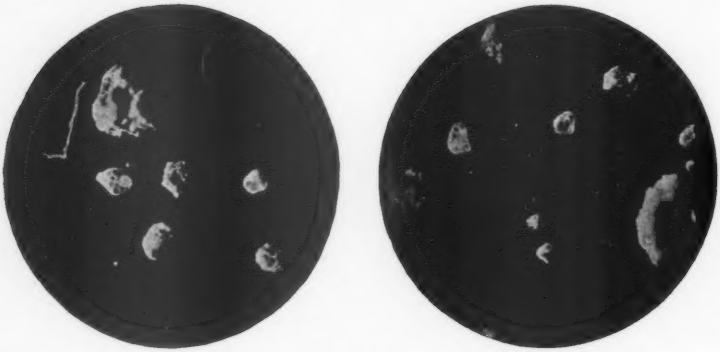


H–2

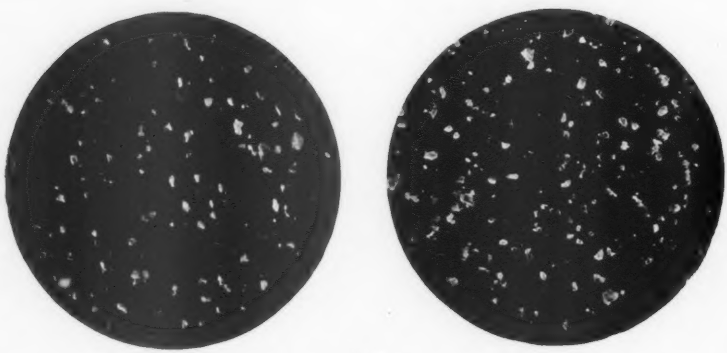


H–3

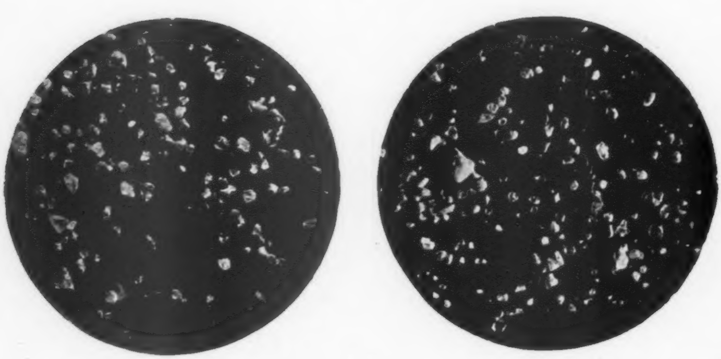
(51)



H-4

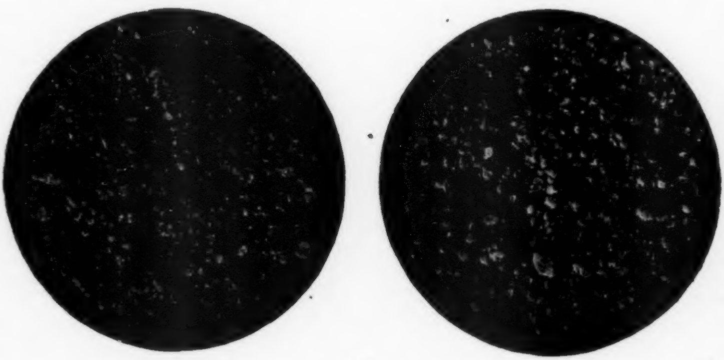


K-1



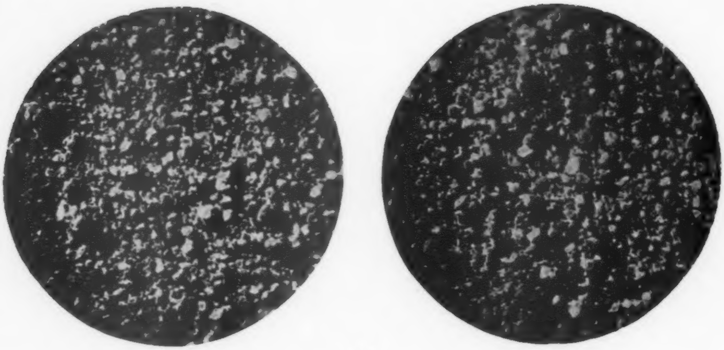
L-1
(52)

L–2

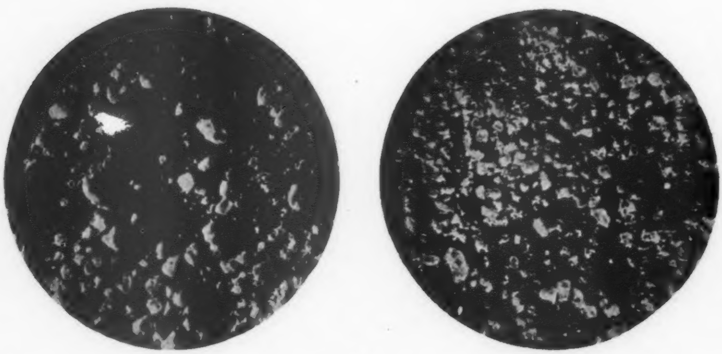


L–3

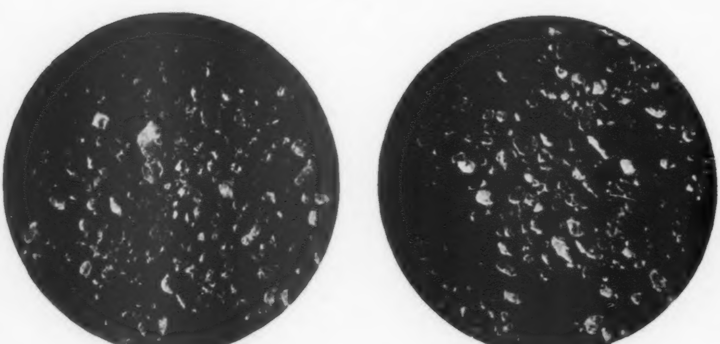
L–4
(53)



L-5

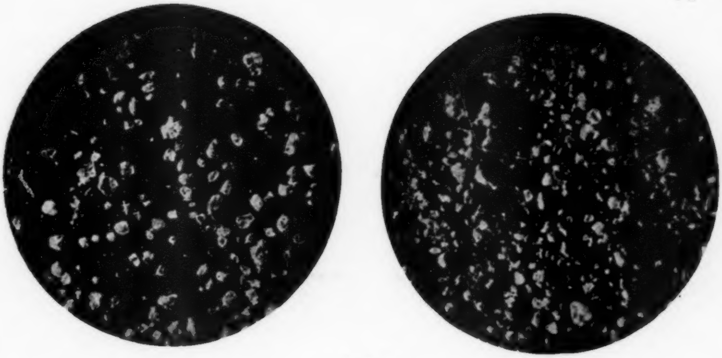


L-6

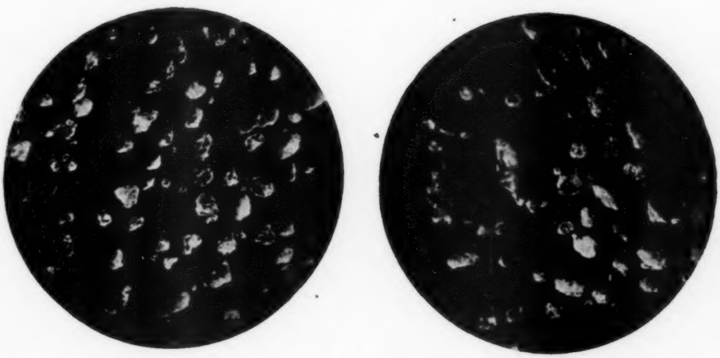


L-7

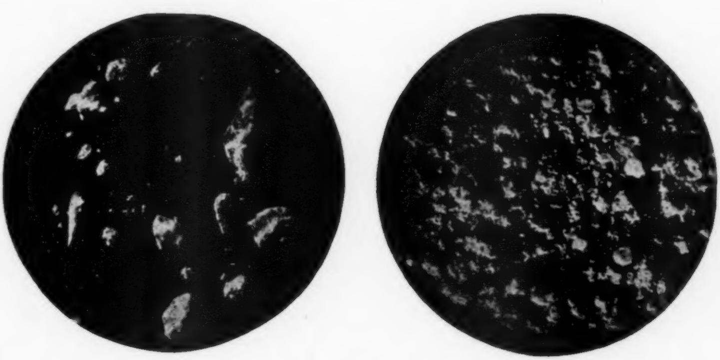
(54)



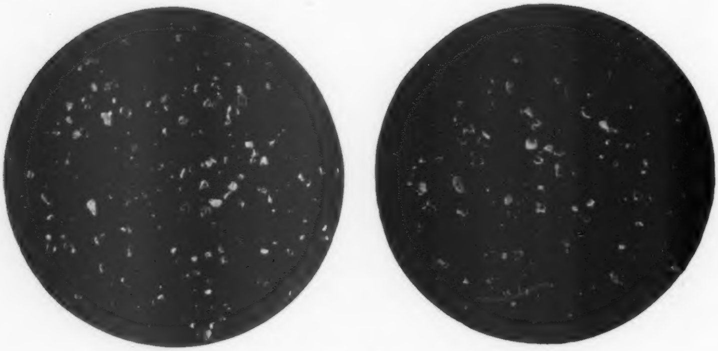
L-8



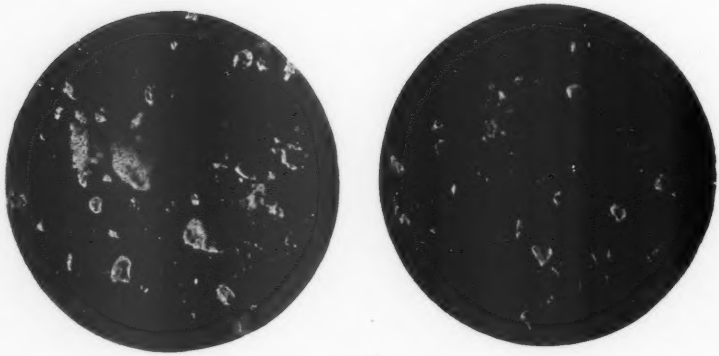
L-9



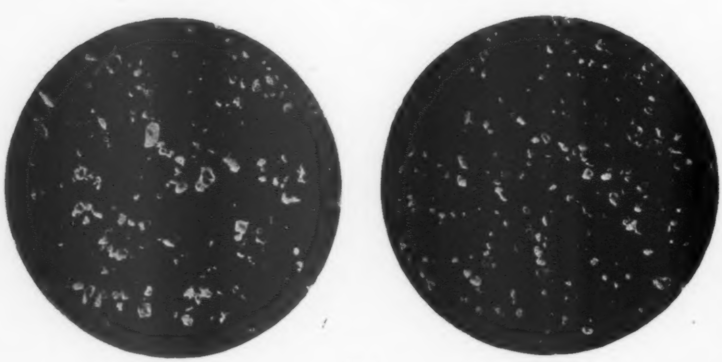
L-10
(55)



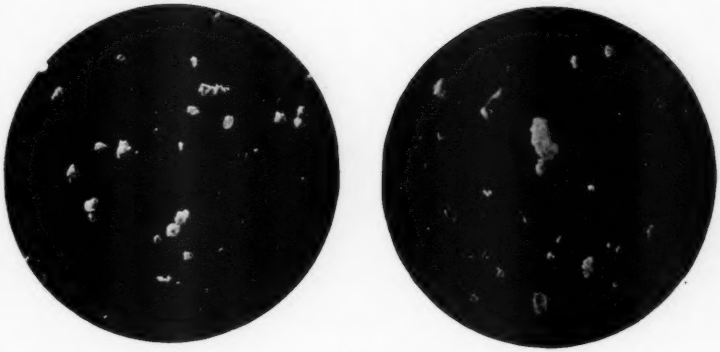
M-1



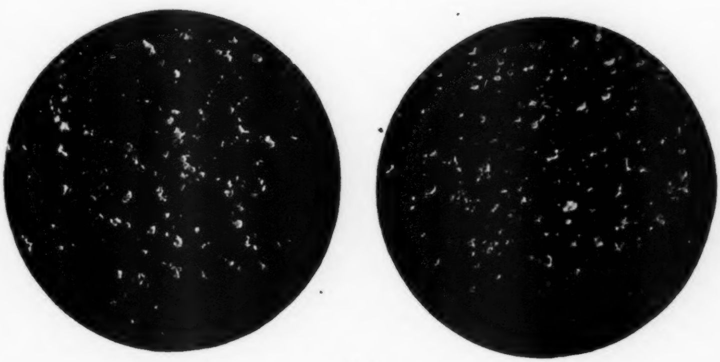
M-2



M-3
(56)

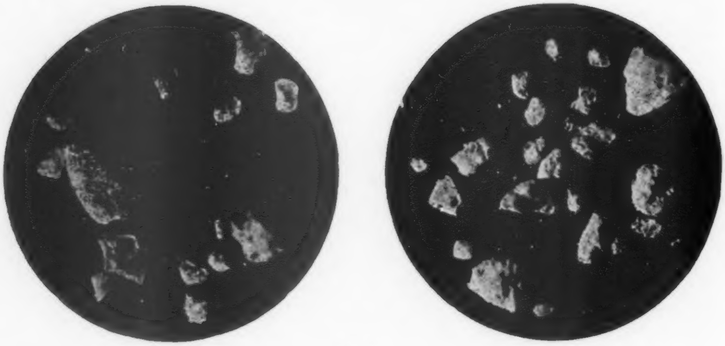


M–4

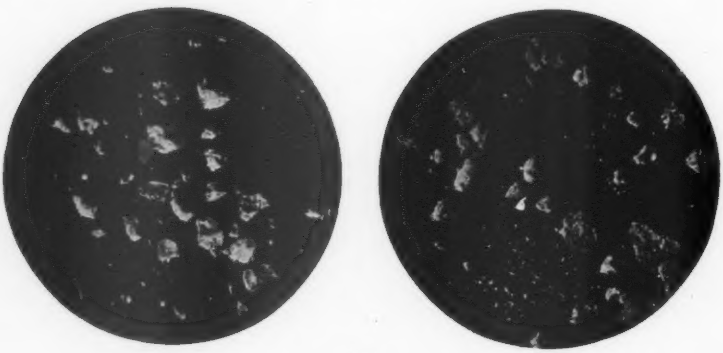


M–5

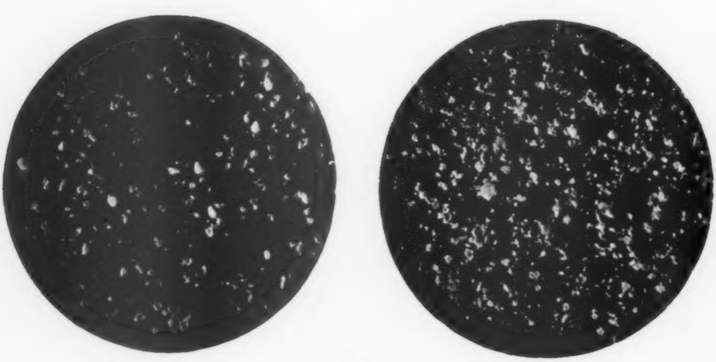
N–1



N–2

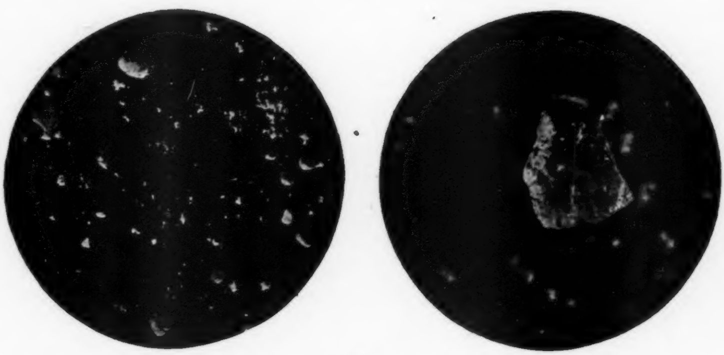


N–3

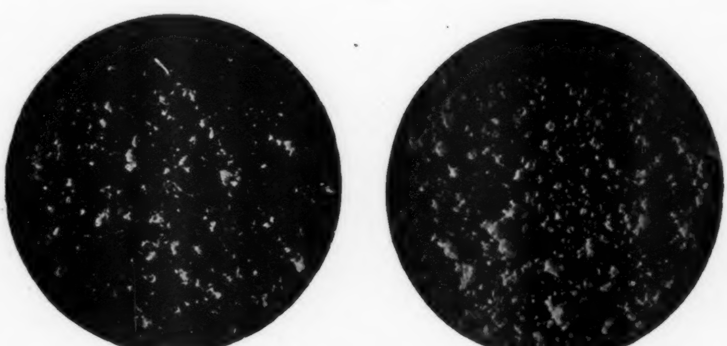


O–1
(58)

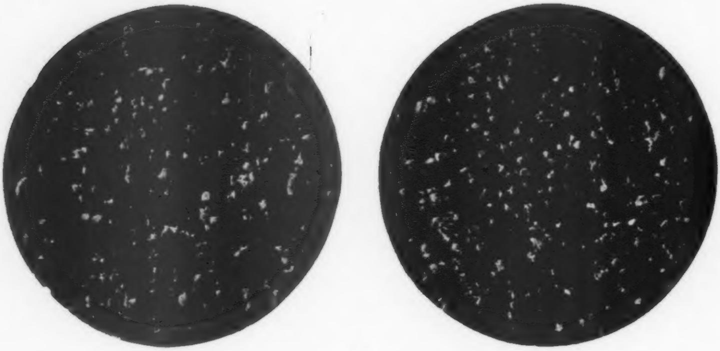
O–2



O–3

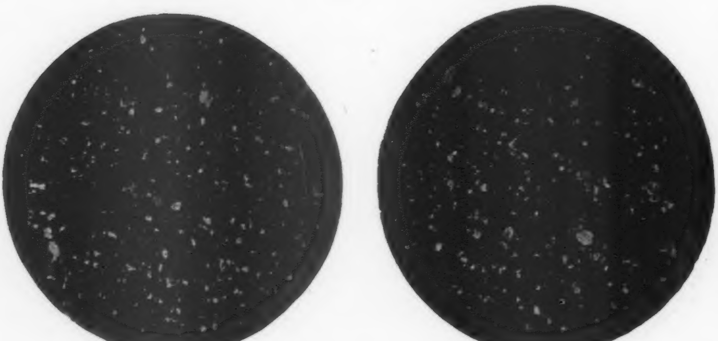


O–4

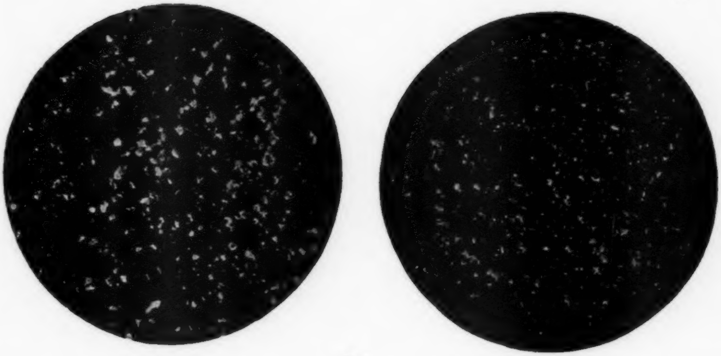


P–1

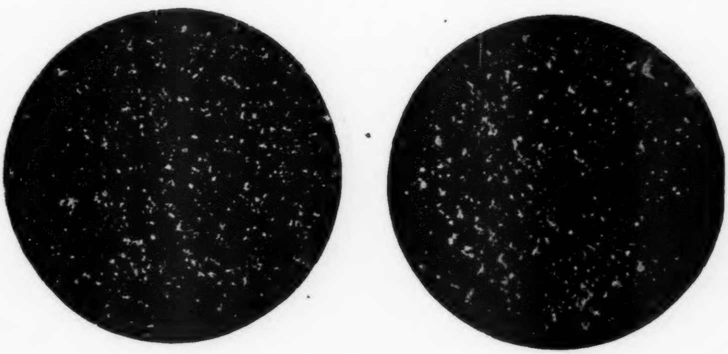
P–2



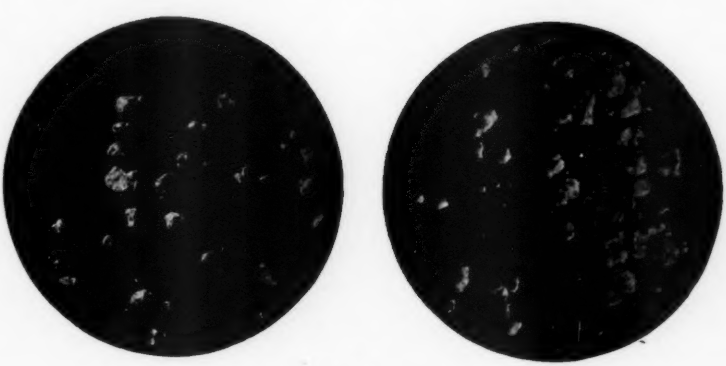
P–3
(60)



P-4

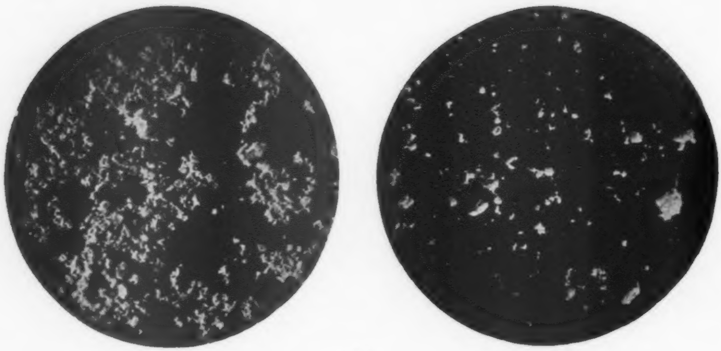


P-5

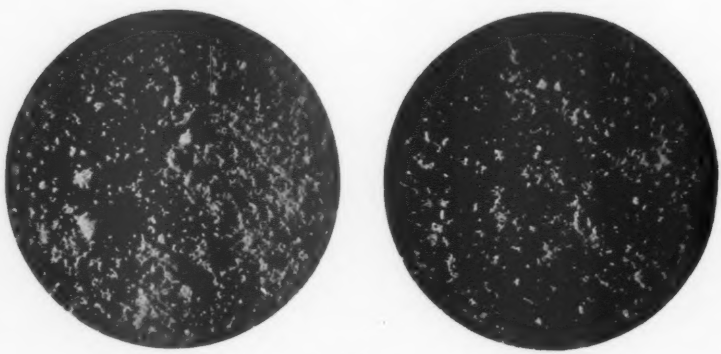


R-1

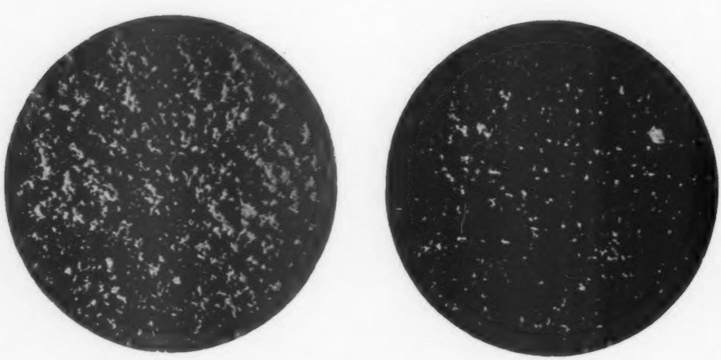
(61)



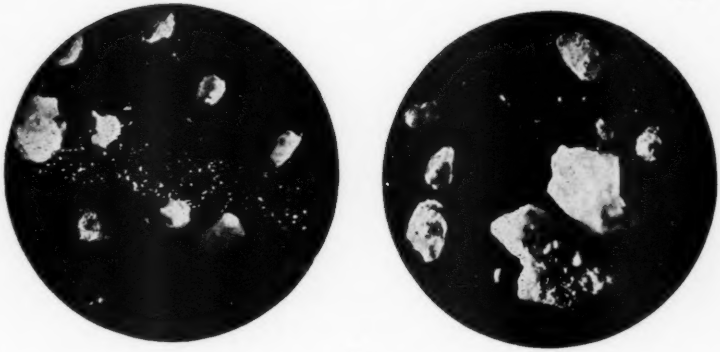
S–1



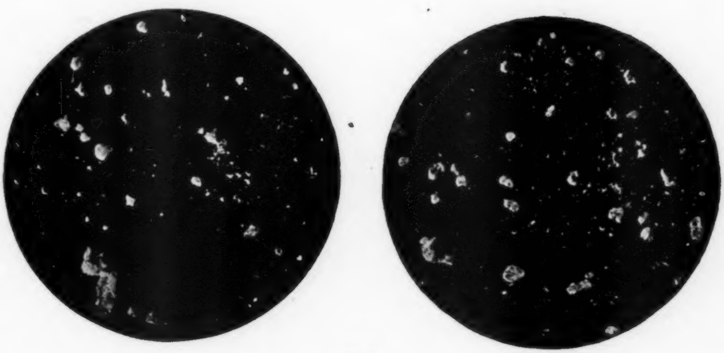
T–1



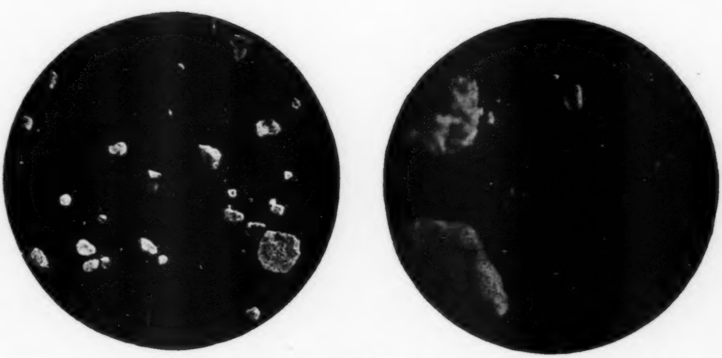
T–2



U–1

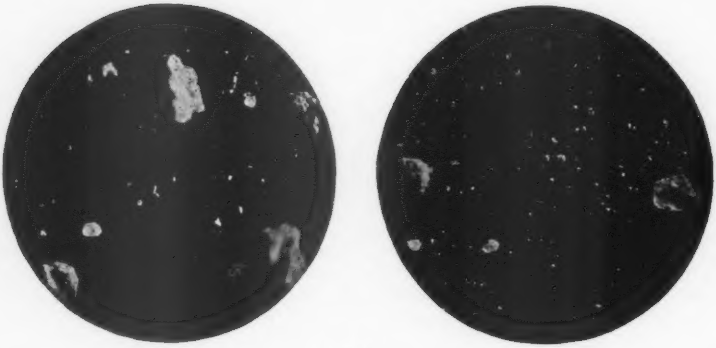


U–2

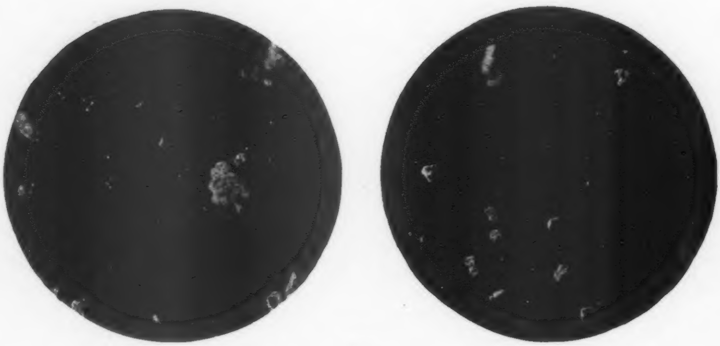


U–3

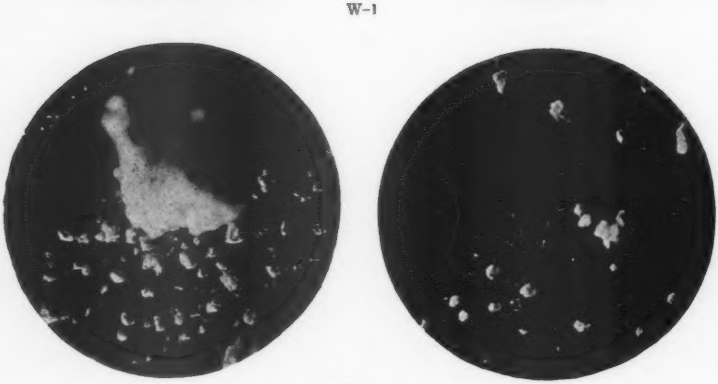
(63)



V–1

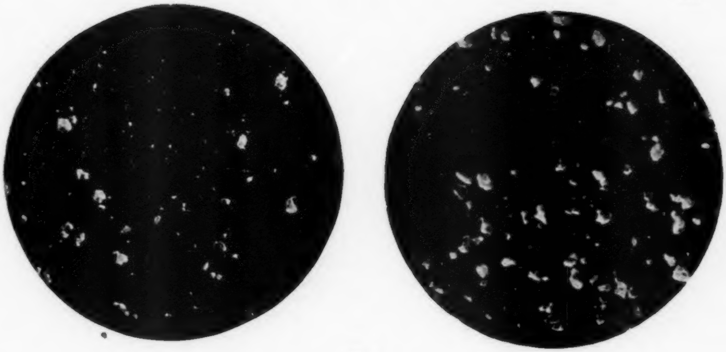


W–1

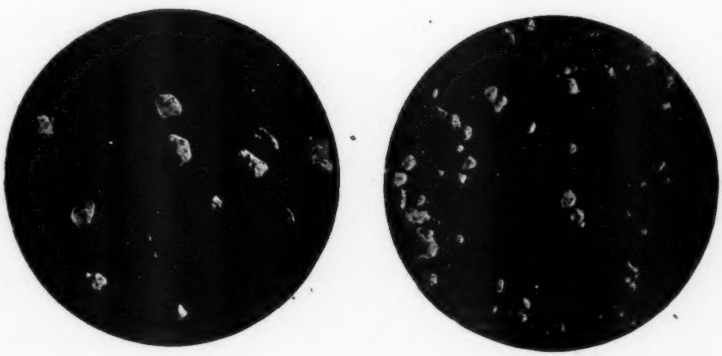


W–2

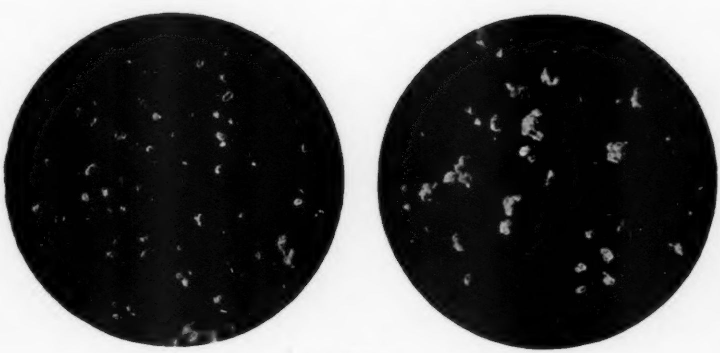
(64)



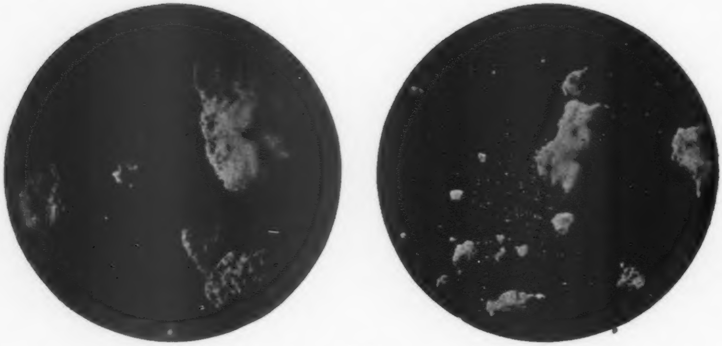
W–3



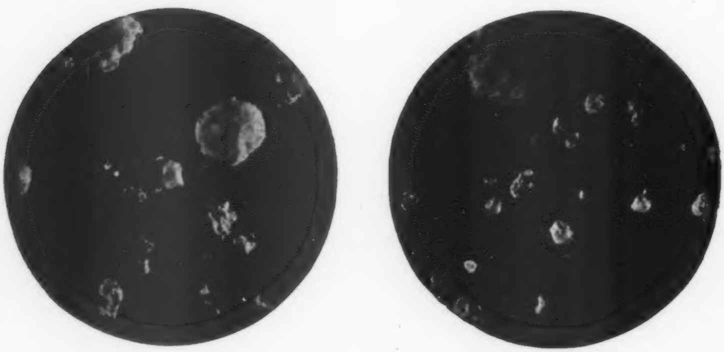
W–4



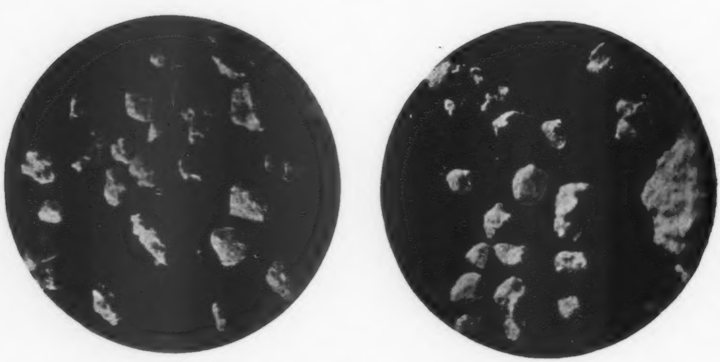
X–1
(65)



Y-1

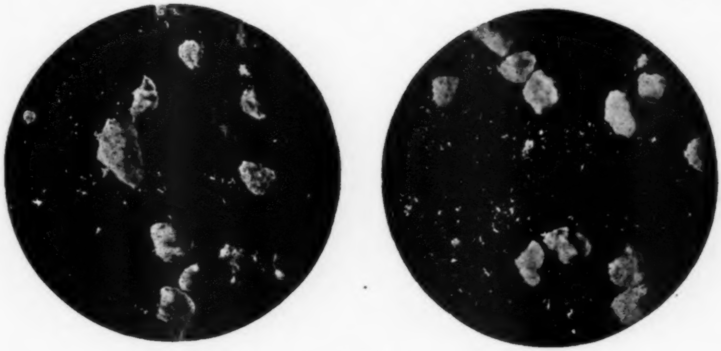


Z-1

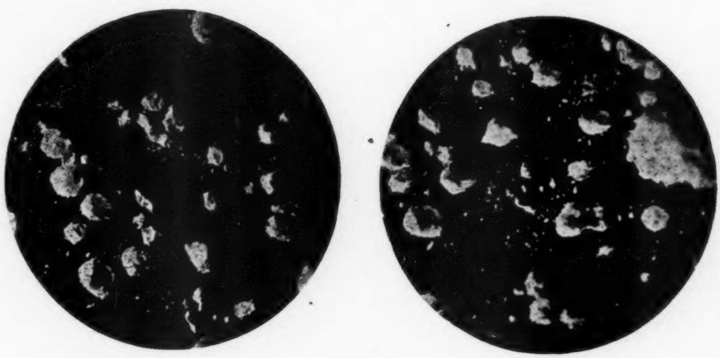


AA-2

(66)



AA-5



BB-2

BB-5

(67)

MOLDING SAND TESTS.

Rational Analysis of the Molding Sands Tested.

The elaborate series of analyses given herewith was carried out under the direction of Mr. H. E. Field, of Mackintosh, Hemphill & Co., Pittsburgh, Pa. The work was done in the laboratory of that company, and credit is due to Mr. F. H. Daniels for much of it, as well as to the company for the courtesy of placing their facilities at the disposal of our Association.

The rational analysis of a molding sand differs from the ultimate chemical analysis in the following: In the ultimate analysis of sands or of clays, the several elements are separated out and their percentages determined. In the case of a rational analysis, these materials are analyzed for their content of quartz, clay substance and feldspar. That is to say, information is wanted as to how far the disintegration of the original granite from which these sands and clays have come had progressed when the molding sand was deposited by the subsequent action of wind and water.

Granite being composed of quartz, feldspars and micas, the quartz of the rational analysis represents that portion of the granite, the clay substance and feldspar are the more or less decomposed feldspars, the micas owing to their lightness having washed away almost altogether. Depending upon the degree of disintegration of the feldspars, we have the refractory properties of the molding sands, for feldspars are usually fusible at molten iron temperatures, whereas clays free from undecomposed feldspars are highly refractory.

The binding power of the clay substance in the molding sands tested will be the subject of a special report. Similarly the action of high temperatures on the clays of molding sands will come in for special study.

The following method for the rational analysis of a molding sand has been contributed by Mr. Field:

"RATIONAL ANALYSIS OF SAND."

Place one gram of the sample in a 150 cc. Griffin Jena glass beaker (sample should previously have been ground to 100 mesh and dried at 100° C. for one hour). Moisten the sample with about 5 cc. water, than add 15 cc. H_2SO_4—1.84 sp. gr. Stir the mixture well, cover with a watch glass and digest on the hot plate for 12 hours at a temperature high enough to make the acid fume. Remove the beaker, allow it to cool and dilute with 100 cc. cold water. Stir thoroughly, bring to a boil and filter through a close filter (S. & S. No. 589 Blue Ribbon), washing well with hot water. Discard the filtrate (see note), replace the paper and residue in the original beaker and digest this time with 100 cc. of 10 per cent *NaOH* solution for 30 minutes at boiling temperature. Filter again through a close filter, washing by decantation three times with 1 per cent *NaOH* solution, leaving the bulk of the filter paper and the residue in the beaker. To this add 50 cc. hot 1–3 *HCl*, stir thoroughly, then continue the filtration and transfer the contents of the beaker to the filter. Wash well with hot water until the washings are free from chlorides. Burn the residue "wet" in a weighed platinum crucible and ignite to constant weight. The weight obtained is the weight of the quartz plus feldspar. This weight subtracted from one gram gives the weight of "clay substance" in the sample.

Fuse this quartz plus feldspar residue with five times its weight of Na_2CO_3 in the platinum crucible and determine the alumina present. This is the alumina of the feldspar. Calculate the weight of the feldspars, subtract it from the weight of the quartz plus feldspar, and obtain the weight of the quartz.

Feldspar, $Al_2 O_3, K_2O, 6 SiO_4$—18.34% Al_2O_3

NOTE:—To obtain the approximate ultimate analysis of the sand, instead of discarding this filtrate containing the sulphuric acid solution of the iron and alumina of the clay substance, oxidize it with bromine, precipitate the iron and alumina with ammonia and determine their respective weights. Using these two additional results, together with the rational analysis and the formula given below, calculate the ultimate composition.

Total Silica.—The percentage of quartz plus 64.74 per cent feldspar plus 46.51 per cent (clay substance minus iron oxide).

Total Alumina.—The alumina of the clay substance plus the alumina of the feldspar.

Total Iron Oxide.—The iron oxide of the clay substance.

Total Alkali.—16.9 per cent of the feldspar.

Rational Analyses of Molding Sands Tested.

Natural Molding Sands.

Mark.	Quartz.	Clay Substance.	Feldspar.
A-1	64.47	26.80	8.73
B-1	68.77	27.92	3.31
B-2	64.70	23.35	11.95
B-3	67.65	19.85	12.50
B-4	65.25	21.95	12.80
B-5	45.55	30.52	23.93
B-6	67.28	28.10	4.62
B-7	65.09	29.75	5.16
B-8	70.99	21.70	7.31
C-1	69.40	25.33	5.27
C-2	71.52	20.90	7.58
C-3	72.70	23.76	3.54
C-4	74.41	21.44	4.15
C-5	72.05	18.05	9.90
C-6	77.00	19.44	3.46
D-1	63.61	21.60	14.79
D-2	63.77	15.50	20.73
D-3	64.49	13.80	21.71
E-1	48.58	18.99	32.43
F-1	57.08	16.92	26.00
F-2	58.24	14.15	27.61
F-3	57.71	18.89	23.40
F-4	56.91	20.17	22.92
F-5	48.59	21.35	30.06
F-6	45.77	24.23	30.00
G-1	63.90	25.24	10.86
G-2	56.91	21.36	21.73
G-3	63.97	18.08	17.95

Mark.	Quartz.	Clay Substance.	Feldspar.
G-4	64.80	25.95	9.25
G-5	78.52	18.60	2.88
G-6	60.13	26.27	13.60
G-7	77.76	18.65	3.59
G-8	57.71	32.19	10.10
H-1	76.57	20.17	3.26
H-2	78.03	18.28	3.69
H-3	78.99	17.37	3.64
H-4	75.49	17.99	6.52
K-1	76.85	13.38	9.77
L- 1	67.31	13.68	19.01
L- 2	58.01	17.70	24.29
L- 3	56.76	14.40	28.84
L- 4	61.88	14.19	23.93
L- 5	57.94	18.94	23.12
L- 6	63.13	22.77	14.10
L- 7	56.92	22.57	20.51
L- 8	49.50	24.87	25.63
L- 9	61.66	20.33	18.01
L-10	59.07	27.90	13.03
M-1	64.48	18.85	16.67
M-2	65.45	20.36	14.19
M-3	61.28	18.16	20.56
M-4	59.79	22.10	18.11
M-5	64.36	19.35	16.29
N-1	55.00	41.20	3.80
N-2	63.50	30.25	6.25
N-3	58.65	32.54	8.81
O-1	61.59	16.68	21.73
O-2	54.52	17.10	28.38
O-3	55.92	20.08	24.00
O-4	72.66	19.17	8.17
P-1	59.06	29.80	11.14
P-2	62.78	23.30	13.92
P-3	68.46	19.68	11.86
P-4	67.90	21.40	10.70
P-5	65.45	24.78	9.77

Mark.	Quartz.	Clay Substance.	Feldspar.
R-1	71.06	26.44	2.50
S-1	60.20	26.28	13.52
T-1	59.79	27.50	12.71
T-2	57.47	29.78	12.75
U-1	88.70	8.85	2.45
U-2	81.55	15.45	3.00
U-3	83.06	13.67	3.27
V-1	70.82	16.65	12.53
W-1	68.58	28 10	3.32
W-2	70.62	26.82	2.56
W-3	78.52	18.37	3.11
W-4	71.81	25.85	2.34
X-1	77.37	17.94	4.69
Y-1	74.53	21.11	4.36
Z-1	72.20	23.99	3.81

Artificial Molding Sands.

There were used in the make-up of these molding sands the following:

(*a*) A very sharp sand—practically a crushed quartz. Composition taken as:

Quartz, 100.00 No Clay Substance. No Feldspar.

(*b*) A very round sand—absolutely clean and white. Free from clay and feldspar. Hence quartz taken at 100.00 also.

(*c*) A very fat clay (rated by U. S. Geological Survey at 100 per cent in scale for fatness of clays).

Quartz, 15.28. Clay Substance, 82.98. Feldspar, 1.74.

(*d*) A very lean clay (rated at 18.5 per cent in scale for fatness of clays, or very lean).

Quartz, 5.77. Clay Substance, 90.69. Feldspar, 3.54.

The following approximate ultimate analyses calculated by the

method above described indicate the excellent quality of these clays:

	Fat Clay.	Lean Clay.
SiO_2	54.60	50.34
Al_2O_3	32.33	36.60
Fe_2O_3	.92	.61
Alkalies	.29	.60

The mixtures were made as follows: 80 per cent, 70 per cent and 60 per cent respectively of the sharp sand (*a*) was mixed with 20 per cent, 30 per cent and 40 per cent respectively of the fat clay (*c*). These mixtures were designated AA-1, AA-2 and AA-3. The same percentages of the sharp sand (*a*) were mixed similarly with the lean clay (*d*) and called AA-4, AA-5 and AA-6. Next the same operation was performed with the round sand (*b*) mixed with the fat clay (*c*) and called BB-1, BB-2 and BB-3; and the round sand (*b*) mixed with the lean clay (*d*) and called BB-4, BB-5 and BB-6.

The calculated rational analyses of these several artificial molding sand mixtures would then be as follows:

Mark.	Quartz.	Clay Substance.	Feldspar.
AA-1	83.06	16.59	0.35
AA-2	74.58	24.89	0.53
AA-3	66.11	33.19	0.70
AA-4	81.15	18.14	0.71
AA-5	71.73	27.21	1.06
AA-6	62.31	36.28	1.41
BB-1	83.06	16.59	0.35
BB-2	74.58	24.89	0.53
BB-3	66.11	33.19	0.70
BB-4	81.15	18.14	0.71
BB-5	71.73	27.21	1.06
BB-6	62.31	36.28	1.41

A comparison with the natural molding sands will show that mixtures of 70 per cent sand with 30 per cent clay correspond to the average; while 80 per cent sand with 20 per cent of either clay is about the extreme in one direction (corresponding to the U samples, with their high quartz percentages), and 60 per cent

sand with 40 per cent clay similarly the extreme in the other direction, the percentage of clay being very high.

As stated previously, a special study is being made on the binding power of the clay substance in all the above molding sands, as a sand may have a high percentage of clay and yet be very weak, and vice versa.

Attention is again directed to the fact that all the analyses given of these molding sands are "rational" ones, and hence those who are accustomed to judge a molding sand for its binding power by the content of "alumina" will wonder at the comparatively high percentages of "clay substance." If they remember that clays are about half "silica" and only one-third "alumina" (as may be seen by the analyses given for the "fat" and the "lean" clays used for the artificial molding sands), they will note that the "alumina" percentages of the molding sands average less than 10 per cent, and the "silica" over 80 per cent.

MOLDING SAND TESTS.

Fineness.

All sands as they were received were stored in a warm room and held until completely dry. Each sand in turn was spread upon the clean concrete floor, the lumps well crushed, and then mixed thoroughly with a molder's shovel. The heap thus made—all the sand received and dried was used—was then divided into quarters, as in getting an ore sample, and two opposite quarters removed and taken back to the storage receptacle again.. The remaining two quarters were then again mixed and divided into quarters, two of which opposite and at right angles to the previous quarters, were again returned to the receptacle. This process was repeated until only several pounds remained for the sample. From this 2,500 grains Adv. (a little over a third of a pound) was kept for the fineness test, and the rest bottled for further investigations.

The quantity taken for the fineness test was then put through a regulation set of sieves, the sub-divisions obtained weighed, and the percentages calculated. The results are given in the accompanying table. The sub-divisions in question are first what remains on a 20-mesh sieve (this means twenty meshes to the inch, or 400 to the square inch of sieve area). Then what remains on the 40-mesh sieve after having passed through the 20-mesh. Next the 40–60-mesh, then the 60–80, the 80–100, and finally what has passed through the 100-mesh sieve. Material that will pass through the 100-mesh, or 10,000 openings per square inch, is pretty fine, and yet some of the sands on the list which are known to be most excellent for fine art brass castings have percentages up in the nineties passing through the 100-mesh sieve.

The last column of the table gives the average fineness in percentages, a hypothetical sand every particle of which would pass through the 100-mesh sieve being considered 100 per cent.

This percentage of average fineness is an approximate one and only intended to serve for purposes of comparison. It is obtained by multiplying the weight of sand passing through each mesh, and retained by the next smaller mesh, by the number of the mesh and dividing the sum of these products by 100. Thus, the calculation for A-1 would be as follows:

0.20%	times	0	(retained by 20 mesh) equals	0.00
1.44%	"	20	(passed through 20 mesh) equals	28.80
1.32%	"	40	(" " 40 ") "	52.80
1.40%	"	60	(" " 60 ") "	84.00
0.24%	"	80	(" " 80 ") "	19.20
95.40%	"	100	(" " 100 ") "	9540.00
100.00%				9724.80

or 97.25 per cent average fineness.

Again for P-3, we have:

0.04%	times	20	equals	0.80
0.20%	"	60	"	12.00
1.48%	"	80	"	118.40
98.28%	"	100	"	9828.00
100.00%				9959.20

or 99.59 per cent average fineness.

The resulting table is of considerable interest. Nearly all the sands having been contributed by the dealers in that commodity, those of each firm are grouped under one designating letter —in some cases over half a dozen grades of molding sand came from one party. As a rule these sands are arranged beginning with the No. 0 sizes and run 1, 2, 3, 4, etc., as in trade. A glance at the tables will show a corresponding fineness, very high percentages going with the early numbers. Occasionally the last numbers of a group run up in fineness, which is due to the receipt of additional samples of sand after the first set had been tested.

Where there are but one or two items to the designating letter, the sand came from foundrymen who use a local sand not usually carried by the dealers.

The table following should be compared with the micrographs in a previous portion of this report in order to judge the physical structure of the sands properly and in comparison with each other.

MOLDING SAND TESTS.

Percentage of Average Fineness.

Natural Molding Sands.

Mark	Per cent over 20 Mesh	Per cent between 20–40	Per cent between 40–60	Per cent between 60–80	Per cent between 80–100	Per cent over 100 Mesh	Per cent Average Fineness
A-1	.20	1.44	1.32	1.40	.24	95.40	97.25
B-1	....	5.76	28.40	19.68	8.80	37.36	68.72
B-2	....	.20	7.28	4.40	3.24	84.88	93.06
B-3	.20	21.64	34.92	17.60	6.52	19.12	53.19
B-4	....	....	.40	3.04	2.08	94.48	98.13
B-5	.20	....	5.92	6.00	3.36	84.52	93.18
B-6	....	4.20	13.92	33.36	17.36	31.16	71.47
B-7	.88	19.84	8.36	5.64	6.36	58.92	74.70
B-8	....	....	6.52	3.92	1.52	88.04	94.21
C-1	....	.04	4.28	4.52	2.92	88.24	95.01
C-2	....	2.40	20.00	16.28	8.28	53.04	77.91
C-3	.04	14.40	36.00	16.80	7.72	25.04	58.58
C-4	.24	29.60	32.00	18.40	2.84	16.92	48.95
C-5	9.24	37.44	21.60	8.20	6.80	16.72	43.21
C-6	....	8.24	27.40	13.00	7.40	43.96	70.29
D-1	.08	1.12	1.92	1.40	1.24	94.24	97.06
D-2	.44	2.80	9.00	16.32	16.56	54.88	82.08
D-3	1.84	31.40	19.88	10.12	9.00	27.76	55.26
E-1	.24	1.60	10.44	6.40	11.68	69.64	87.32
F-1	....	.12	.40	.44	.52	98.52	99.38
F-2	....	.12	.56	.60	.56	98.16	99.22
F-3	....	.60	3.08	13.00	23.52	59.80	87.77
F-4	.08	8.36	17.60	28.24	20.16	25.56	67.34
F-5	.20	11.80	21.80	12.16	25.28	28.76	67.36
F-6	.28	35.04	32.00	13.28	9.52	9.88	45.27
G-1	....	.08	8.24	3.72	2.08	85.88	93.09
G-2	....	8.00	29.20	22.96	12.00	27.84	64.50
G-3	....	15.72	28.00	18.00	7.60	30.68	61.90
G-4	....	6.00	13.20	16.32	10.00	54.48	78.75
G-5	....	31.40	38.04	12.00	4.60	13.96	46.34
G-6	.68	30.80	8.92	4.56	5.60	49.44	66.38
G-7	2.84	40.00	27.20	9.60	4.80	15.56	44.04
G-8	.04	.60	4.20	5.28	3.20	86.68	92.21

Mark	Per cent over 20 Mesh	Per cent between 20–40	Per cent between 40–60	Per cent between 60–80	Per cent between 80–100	Per cent over 100 Mesh	Per cent Average Fineness
H-1	.08	.24	6.80	8.84	9.76	74.28	90.16
H-2	.04	.32	7.36	11.56	11.48	69.24	88.37
H-3	.04	3.60	14.44	22.88	12.36	46.68	76.79
H-4	.08	4.92	36.96	18.80	7.60	31.64	64.76
K-1	.04	.16	.88	4.52	9.04	85.36	95.69
L- 1	.16	1.56	7.04	16.40	19.24	55.60	83.96
L- 2	8.72	55.00	10.40	5.60	2.28	18.00	38.34
L- 3	4.52	19.68	11.60	8.28	5.64	50.28	68.34
L- 4	.08	3.44	4.00	8.84	14.80	68.84	88.27
L- 5	.16	13.88	5.60	3.84	7.52	69.00	82.34
L- 6	.36	12.56	15.20	11.12	7.48	53.28	74.53
L- 7	....	1.36	30.24	22.80	14.08	31.52	68.56
L- 8	.96	9.56	13.68	16.80	6.80	52.20	75.10
L- 9	....	9.80	41.24	19.40	7.40	22.16	58.18
L-10	4.60	33.44	25.24	14.24	5.36	17.12	46.74
M-1	....	1.04	1.36	4.40	3.72	89.48	95.85
M-2	....	.84	7.72	9.76	11.80	69.88	88.43
M-3	.04	1.44	12.08	16.80	11.32	58.32	82.58
M-4	....	.04	3.04	5.36	6.12	85.44	94.78
M-5	.04	3.92	14.24	17.04	11.84	52.92	79.10
N-1	1.48	8.24	35.56	20.68	6.64	27.40	60.99
N-2	3.20	20.16	48.80	11.20	3.68	12.96	46.18
N-3	.80	25.44	35.52	13.88	5.64	18.72	50.86
O-1	.04	1.04	1.88	2.60	5.00	89.44	95.96
O-2	2.04	6.60	12.48	8.48	6.00	64.40	80.60
O-3	.40	2.92	27.20	20.00	10.92	38.56	70.76
O-4	1.28	11.64	20.68	17.40	8.60	40.40	68.32
P-1	....	.08	10.52	8.60	9.00	71.80	88.38
P-2	....	.12	6.88	7.52	8.60	76.88	91.05
P-3	....	.04	....	.20	1.48	98.28	99.59
P-4	....	.08	.08	.52	6.40	92.92	98.40
P-5	....	.28	.40	.48	.60	98.24	99.22
R-1	.04	14.52	30.84	18.72	8.20	27.68	60.71
S-1	.48	1.16	15.20	10.68	9.84	62.64	83.23
T-1	.40	19.20	9.80	5.88	4.80	59.88	75.04
T-2	.32	14.40	14.48	9.68	3.44	57.68	74.91

Mark	Per cent over 20 Mesh	Per cent between 20–40	Per cent between 40–60	Per cent between 60–80	Per cent between 80–100	Per cent over 100 Mesh	Per cent Average Fineness
U-1	17.12	37.36	19.44	9.04	4.16	12.88	36.88
U-2	5.76	12.72	39.60	16.24	3.92	21.76	53.02
U-3	6.32	29.60	18.56	20.32	10.88	14.32	48.56
V-1	2.56	39.60	34.16	5.52	1.36	16.80	42.78
W-1	.12	11.20	44.08	11.00	7.44	26.16	58.58
W-2	.24	4.00	42.16	19.28	11.68	22.64	61.22
W-3	.32	7.52	33.76	24.08	7.36	26.96	62.30
W-4	.24	9.92	62.00	8.00	6.40	13.44	50.14
X-1	.08	.24	36.00	14.48	15.36	33.84	69.26
Y-1	7.20	25.76	38.96	10.48	4.48	13.12	43.73
Z-1	5.36	28.88	26.48	16.00	11.48	11.80	46.95
		Artificial Molding Sands.					
AA-1	5.04	16.80	28.24	17.88	17.04	15.00	54.02
AA-2	4.80	20.92	30.72	9.04	18.16	16.36	52.78
AA-3	4.48	23.84	26.24	11.28	16.32	17.84	52.93
AA-4	4.24	21.68	36.28	24.20	11.52	2.08	44.66
AA-5	4.24	25.28	39.52	19.00	8.56	3.40	42.51
AA-6	3.20	42.88	32.00	14.16	4.56	3.20	36.72
BB-1	2.72	16.04	32.56	22.40	11.28	15.00	53.70
BB-2	4.32	17.84	39.92	17.64	9.88	10.40	48.42
BB-3	4.00	27.92	28.08	18.40	10.56	11.04	47.34
BB-4	9.84	20.80	32.64	17.60	10.00	9.12	44.90
BB-5	4.72	26.24	41.28	19.52	6.20	2.04	40.47
BB-6	2.72	36.00	42.96	14.52	2.88	.92	36.32
Sharp sand in AA-1–6	6.00	10.32	28.44	18.08	6.16	31.00	60.22
Round sand in BB-1–6	.64	5.12	35.40	31.08	13.60	14.16	58.87

MOLDING SAND TESTS.

Transverse Strength.

In making the physical tests on the molding sand series, each sand was tempered and the test specimens were prepared under as nearly identical conditions as possible. This would make the results fairly comparable. The first problem was the tempering of the sand. Depending upon the size of the grain, and the clay content—with very probably the character of the clay—one sand might require more water than another in order to give the best all around molding results. A number of trials were made with sands of different character, and as the result three standards were selected, namely the addition to the perfectly dry sand of 5 per cent, 7½ per cent, and 10 per cent water. The smaller quantity of water would leave most of the sands—especially the fine ones—rather insufficiently tempered, whereas the 10 per cent water addition would work the other way; more particularly with the coarse sands. With the three quantities used, a very fair idea in regard to the requirements of each molding sand, to get the best results from it, could be gathered.

In tempering the sand, the weighed quantity of the dry material was first spread upon the floor of smooth concrete. The weighed amount of water was next sprinkled on this a little at a time, and the sand well worked over. After cutting up thoroughly the batch of tempered sand was put through a No. 8 riddle into an iron tote-box, and well covered with a piece of wax cloth. The sand thus protected from evaporation, was allowed to stand for about two hours to allow a thorough dissemination of the moisture. A sufficient number of these sand batches were prepared during the morning, so that the tests proceeded all day long.

The special flask shown in Fig. 1 was now gotten ready and the sand riddled into it, enough being used to cover the top about an inch. A hand rammer was next used rather gently on the sand all over the mold, compressing the material to about one-quarter of an inch over the mold—just as is done in squeezer or molding

machine work—and the surplus struck off. Next the small pieces of half inch pine shown in Fig. 1, fitting into the compartments of the mold, were laid on and the whole flask and bottom board put under the letter-press, and squeezed flush. The flask being inch and a half deep, the introduction of the half inch strips

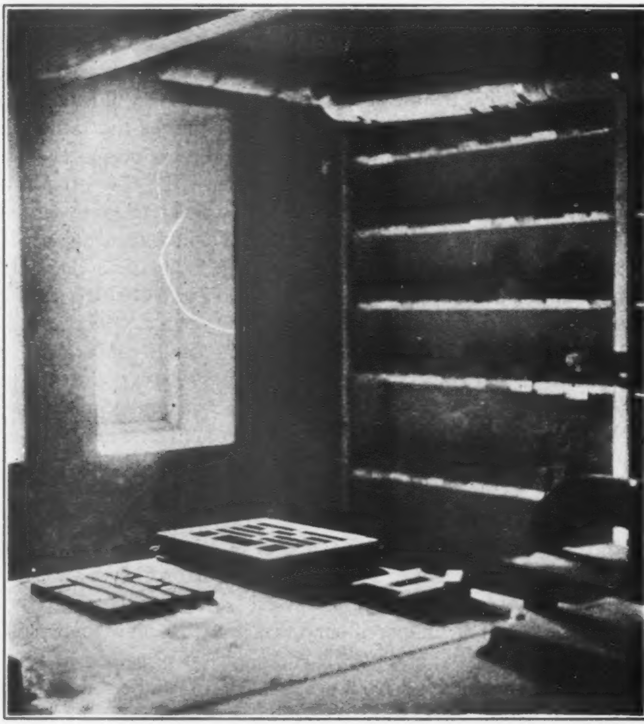


FIG. 1.

left the sand an inch thick. The original tempered sand being compressed only to the extent of what would correspond to slapping down the shovel on it, before pressure was applied, the reduction in volume after that action was to two-thirds. This corresponds to ordinary practice in bench molding.

The completed mold was then removed, the flask swung open, the partitions carefully drawn out—the little blocks of sand being pushed away gently to allow this to be done—and the test pieces were ready for the work in hand. Each of the three molds from every sand sample was made in this manner, and furnished enough test pieces to make at least two transverse tests, two crushing tests, and two tests to determine the permeability of the sand to air. As accidents with the test pieces were quite frequent, another set of molds was always made, and this set furnished sufficient test pieces for drying purposes, so that the strength of the molding sands could also be determined for dry sand work. The drying was done by placing the samples carefully upon plate glass, and on two large hot-water furnaces where they were allowed to remain over night.

The bars for the transverse test were made an inch square and four and a half inches long. They were placed upon supports four inches apart, experiment having shown that a longer distance would mean the breaking of too many sands by their own weight. The load was applied at the center, as shown in Fig. 2. The knife edge placed on the bar of sand and the rod leading down to the bucket were of magnesium, to give the least weight possible. The bucket attached below was of thin sheet aluminum, which is not much heavier. Bird shot was run carefully and gently into this bucket, dropping from just over the bucket to prevent the effect of blows, until the bar failed. The weight, including the knife-edge, etc., was then determined and recorded.

As stated above, two tests were made for every one of the three standards for each sand, and where the discrepancy was great between the results, another or even two more were made, so that an average could be had from two tests which ran pretty close. The breaking weight is given in pounds and decimals thereof, and as the section was an inch square in each case the results are in pounds per square inch, (supports 4 in. apart).

From the results it will be noted that the strength of the dried bars is considerably higher than when the same sand was tempered with 5 per cent, 7½ per cent, or 10 per cent water. A study of the tempered sand shows some interesting facts. At first glance, the higher numbers of the alphabet sets, supposedly corresponding to the coarser sands, show that better strengths are

obtained with the 5 per cent water admixture than with the larger quantities. This is as it should be, for there are fewer grains to wet and hence the water should go further. A number of exceptions, however, must be noted, such as B-5, B-8, which gave the best strength with the 10 per cent water additions. Reference to the fineness tables indicates that these sands run 93.18, and 94.21 per cent, or are really very fine sands. (The trade num-

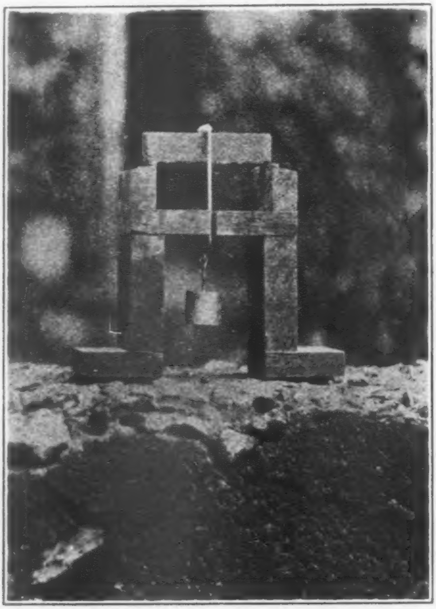


FIG. 2.

bers under which they are sold are No. 4 and No. 5, or coarse sand numbers, which would show that there is room for a revision of this part of the sand business.) On the other hand, a number of sands such as H-1, L-1, L-6, which are graded as No. 1, No. 0, No. 1, give their best transverse strength with 5 per cent water, whereas the reverse would be expected. Here again the fineness tables show that in grading by the eye or touch an error had been

made, for they correspond to 90.16, 83.96, and 74.53 per cent fineness, or are rather coarse.

It would therefore look as if such a test as the transverse would help the molding sand industry develop a line of treatment which would grade sands into classes suited for particular kinds of castings, and for which foundrymen would pay a moderate premium.

The tables follow herewith:

TRANSVERSE TESTS.

BARS 1 IN. SQUARE AND 4½ IN. LONG, BROKEN ON SUPPORTS 4 IN. APART. BREAKING WEIGHT IN POUNDS.

Natural Sands.

Mark	Dry	5 per cent water	7½ per cent water	10 per cent water
A-1	2.93	0.12	0.14	0.18
B-1	0.78	0.48	0.94	0.38
B-2	1.23	0.23	0.21	0.24
B-3	1.59	0.51	0.31	0.18
B-4	0.70	0.19	0.14	0.07
B-5	4.54	0.25	0.18	0.28
B-6	1.07	0.83	0.74	0.63
B-7	1.28	0.53	0.30	0.27
B-8	1.86	0.28	0.31	0.32
C-1	0.30	0.01	0.00	0.13
C-2	2.03	0.17	0.24	0.19
C-3	1.73	0.73	0.35	0.23
C-4	2.85	0.25	0.43	0.32
C-5	1.71	0.09	0.17	0.12
C-6	0.83	0.16	0.08	0.01
D-1	1.22	0.19	0.21	0.19
D-2	1.10	0.05	0.04	0.11
D-3	0.79	0.13	0.14	0.14
E-1	0.93	0.18	0.29	0.15
F-1	1.23	0.15	0.31	0.08
F-2	1.24	0.15	0.21	0.06
F-3	1.29	0.13	0.23	0.09
F-4	1.87	0.84	0.15	0.10

Mark	Dry	5 per cent water	7½ per cent water	10 per cent water
F-5	1.70	0.44	0.18	0.07
F-6	1.22	0.12	0.07	0.00
G-1	0.65	0.18	0.19	0.16
G-2	0.36	0.00	0.10	0.07
G-3	2.13	0.46	0.17	0.34
G-4	0.70	0.22	0.27	0.48
G-5	1.92	0.27	0.73	0.19
G-6	4.14	0.42	0.12	0.17
G-7	0.64	0.89	0.23	0.41
G-8	0.73	0.14	0.23	0.23
H-1	3.57	0.28	0.07	0.03
H-2	2.08	0.13	0.00	0.00
H-3	3.16	0.12	0.12	0.13
H-4	5.75	0.12	0.15	0.14
K-1	0.03	0.17	0.04	0.05
L-1	1.65	0.16	0.03	0.09
L-2	2.55	0.22	0.15	0.10
L-3	0.92	0.22	0.13	0.14
L-4	1.79	0.25	0.19	0.07
L-5	0.86	0.27	0.27	0.16
L-6	1.11	0.35	0.18	0.14
L-7	1.08	0.25	0.16	0.24
L-8	1.54	0.26	0.15	0.12
L-9	1.14	0.17	0.16	0.17
L-10	1.20	0.29	0.14	0.04
M-1	0.47	0.11	0.04	0.04
M-2	0.85	0.07	0.13	0.12
M-3	2.26	0.27	0.15	0.15
M-4	1.94	0.21	0.14	0.07
M-5	1.85	0.28	0.20	0.00
N-1	1.92	1.18	1.05	0.65
N-2	1.01	0.29	0.24	0.14
N-3	1.84	1.86	1.02	0.29
O-1	0.94	0.31	0.14	0.12
O-2	2.25	0.10	0.24	0.07
O-3	4.23	0.30	0.09	0.17
O-4	2.00	0.34	0.26	0.13

Mark	Dry	5 per cent water	7½ per cent water	10 per cent water
P-1	2.65	1.20	0.89	0.25
P-2	2.33	0.15	0.15	0.15
P-3	1.27	0.09	0.13	0.20
P-4	1.02	0.11	0.07	0.06
P-5	1.51	0.27	0.19	0.26
R-1	2.41	0.62	0.30	0.42
S-1	0.31	0.77	0.52	0.28
T-1	3.25	0.16	0.18	0.00
T-2	2.83	0.26	0.24	0.16
U-1	2.28	1.85	0.94	0.97
U-2	1.69	0.17	0.12	0.18
U-3	1.16	0.20	0.11	0.16
V-1	3.74	0.20	0.10	0.57
W-1	2.07	0.51	0.12	0.24
W-2	3.04	0.05	0.75	0.07
W-3	2.10	0.60	0.22	0.18
W-4	1.37	0.18	0.11	0.06
X-1	1.39	0.20	0.40	0.50
Y-1	0.87	0.56	0.30	0.15
Z-1	1.46	0.34	0.30	0.29
Artificial Molding Sands.				
AA-1	1.02	0.47	0.21	0.15
AA-2	0.66	0.59	0.24	0.22
AA-3	1.05	0.69	0.79	0.30
AA-4	0.13	0.15	0.14	0.22
AA-5	0.32	0.23	0.42	0.15
AA-6	0.23	0.28	0.19	0.20
BB-1	0.97	0.26	0.22	0.25
BB-2	0.93	0.42	0.53	0.21
BB-3	0.89	0.77	0.48	0.47
BB-4	1.09	0.14	0.26	0.18
BB-5	0.48	0.11	0.48	0.21
BB-6	0.41	0.12	0.19	0.27

MOLDING SAND TESTS.

Crushing Strength.

The method of preparing the test pieces has been fully discussed in the chapter on the Transverse Strength, hence there need only be added that the test pieces used for measuring the crushing strength were all one inch square by two and one-half inches in height—the latter dimension being the one recommended by the "Committee on Methods of Testing", of the American Society for Testing Materials, for substances of this character and cross-section.

Figs. 1 and 2 illustrate the manner of conducting the tests. The apparatus was of brass, substantially made, the bucket being filled with large shot, as wanted. As many of these small columns of sand were so strong that the bucketful of shot would not crush them, it was often necessary to use the arrangement of Fig. 2, and add weights until the test was accomplished. Take, for instance, the dried B-7, with 49.89 pounds of weights and shot added until the sand column failed. (As the bar was one inch square, the crushing strength was 49.89 lb. per sq. in.—a very high figure.) Or O-3, with even better results—60.30 lb. per sq. in.

The crushing test is a much less delicate one than the transverse. Here the weight is applied directly upon the full cross-section, whereas in the transverse test the load applied at the center produces the maximum stress in the lowest portion of the bar, tending to tear it apart, the same by way of compression at the knife-edge on top, and no strain in the centre. Hence a comparatively light load will break the bar, which means that in pouring iron into a mold, unless the cope is well barred, and can resist the bending action readily, a small head of metal in the pouring basin, or riser, will exert enough pressure to burst it upward. At the same time no appreciable compression of the sand may be noticed in the drag.

The same conditions observed in the transverse test report

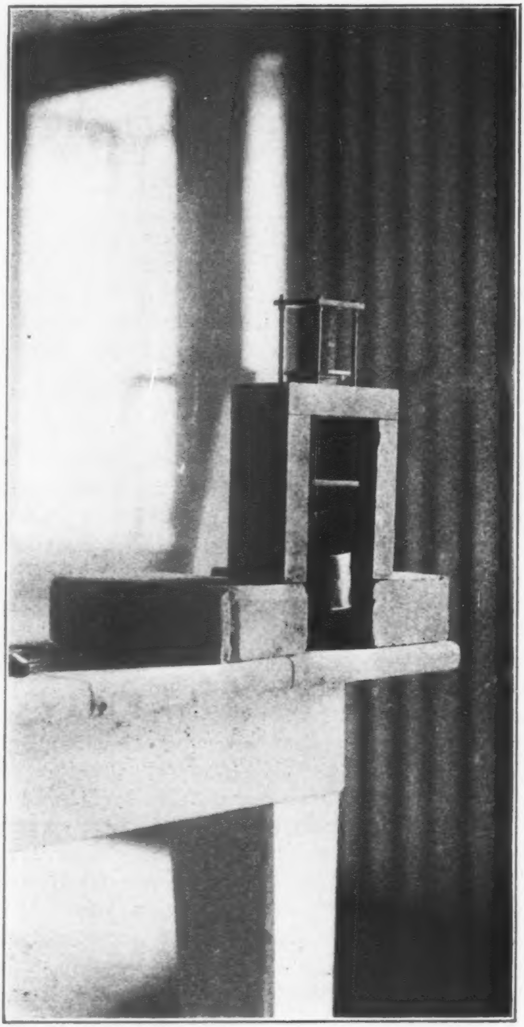


FIG. 1.

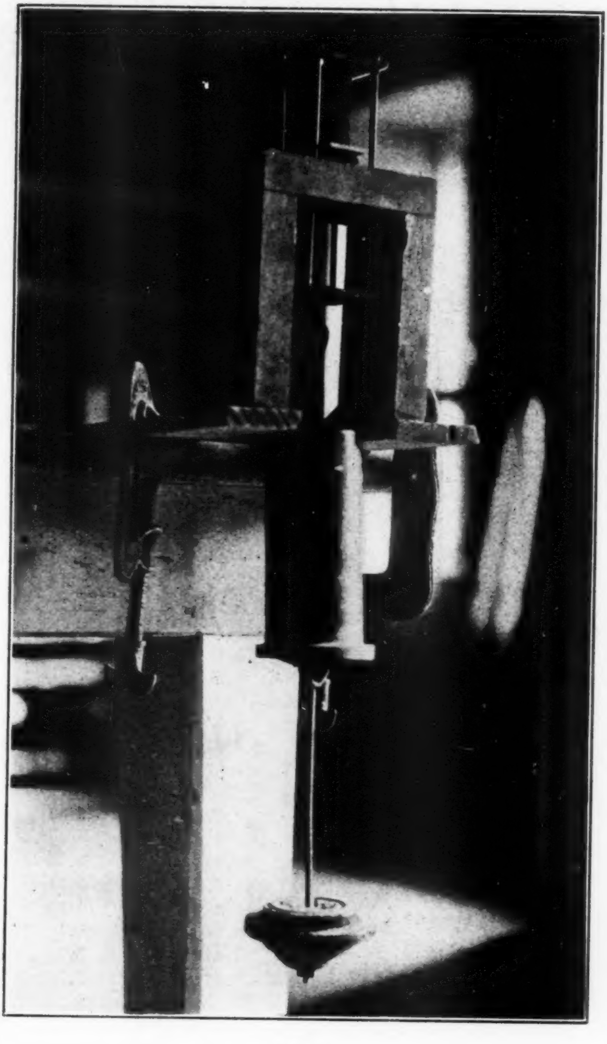


FIG. 2.

will be found in the figures as given in the table below. The coarser sands are shown up best with the smaller amounts of water in tempering, and *vice versa*.

CRUSHING TESTS.

Bars 1 in. Square, and 2½ in. High.

Crushing Weight in Lbs. Per Sq. In.

Natural Sands.

Mark	Dry	5 per cent water	7½ per cent water	10 per cent water
A-1	11.66	1.82	2.40	3.45
B-1	5.66	9.51	7.83	6.65
B-2	3.06	2.43	3.99	1.91
B-3	6.26	6.58	5.93	6.29
B-4	3.12	2.77	1.84	4.11
B-5	24.79	5.23	4.28	3.28
B-6	12.95	12.07	7.11	10.29
B-7	49.89	5.83	5.36	9.01
B-8	8.30	4.65	4.29	3.53
C-1	4.34	3.39	2.10	2.74
C-2	28.29	2.77	2.04	3.31
C-3	5.17	6.64	6.39	10.20
C-4	5.49	7.81	5.92	3.75
C-5	11.11	2.79	2.38	2.63
C-6	5.91	3.58	2.71	3.07
D-1	6.07	2.01	3.09	1.91
D-2	7.42	2.79	1.94	2.13
D-3	4.77	2.41	2.25	1.99
E-1	2.99	2.22	3.63	3.63
F-1	19.43	4.22	4.46	1.97
F-2	6.26	2.80	2.11	2.03
F-3	11.05	3.72	4.89	2.85
F-4	8.76	4.46	5.15	1.99
F-5	4.45	6.24	2.73	4.06
F-6	5.01	2.70	2.78	1.56
G-1	3.80	3.35	3.02	3.73
G-2	3.00	1.99	1.87	1.41
G-3	19.01	5.47	3.52	3.57

Mark	Dry	5 per cent water	7½ per cent water	10 per cent water
G-4	6.60	2.86	3.02	7.01
G-5	14.50	3.34	2.13	2.54
G-6	4.04	6.49	3.60	2.02
G-7	3.51	10.26	2.99	3.89
G-8	6.06	2.76	2.51	3.11
H-1	9.54	5.84	2.58	1.30
H-2	18.15	3.54	1.74	0.97
H-3	11.09	2.22	3.39	3.04
H-4	26.62	2.70	1.88	2.41
K-1	0.78	1.61	2.59	0.78
L-1	11.14	2.41	2.24	2.43
L-2	8.72	2.42	3.05	2.14
L-3	7.49	4.22	2.38	1.75
L-4	10.58	3.84	3.70	1.86
L-5	5.60	3.81	3.30	2.89
L-6	15.09	8.77	3.07	2.66
L-7	5.00	3.84	2.39	2.29
L-8	8.73	4.04	3.55	2.44
L-9	8.42	1.59	2.47	1.69
L-10	15.42	2.41	1.49	1.56
M-1	3.23	1.37	1.63	1.92
M-2	4.58	1.81	2.85	2.03
M-3	27.91	4.38	3.07	2.49
M-4	15.95	2.92	5.32	2.02
M-5	24.92	4.02	3.71	2.77
N-1	13.44	7.55	7.15	4.60
N-2	10.64	5.84	2.94	2.98
N-3	10.27	10.63	12.43	9.78
O-1	6.93	2.14	2.11	1.94
O-2	13.14	1.91	3.62	1.95
O-3	60.30	3.57	2.76	3.32
O-4	15.90	4.35	4.33	3.40
P-1	27.40	9.75	4.63	3.85
P-2	7.46	2.73	2.19	2.75
P-3	4.27	1.82	1.72	1.57
P-4	3.70	1.79	1.93	2.07
P-5	4.55	2.64	4.31	2.74

Mark	Dry	5 per cent water	7½ per cent water	10 per cent water
R-1	7.03	9.83	3.01	7.02
S-1	1.77	8.36	5.98	3.81
T-1	17.60	4.67	2.77	1.86
T-2	19.57	3.09	2.77	3.65
U-1	12.10	1.79	1.73	0.96
U-2	12.29	2.99	1.80	2.88
U-3	18.94	3.94	1.76	1.84
V-1	30.80	5.89	2.95	7.24
W-1	16.34	6.69	3.13	4.71
W-2	28.60	5.19	6.15	3.30
W-3	14.50	8.83	1.91	3.18
W-4	30.70	2.08	1.66	2.10
X-1	4.32	2.80	2.70	1.58
Y-1	5.22	7.92	5.03	0.93
Z-1	24.38	4.18	4.46	2.95
Artificial Molding Sands.				
AA-1	4.71	3.69	2.28	2.52
AA-2	5.56	8.83	2.53	4.23
AA-3	4.96	12.41	7.39	3.06
AA-4	1.61	2.17	2.86	3.01
AA-5	3.11	5.65	4.79	2.18
AA-6	2.55	4.41	3.06	3.04
BB-1	4.88	4.50	3.10	2.67
BB-2	4.51	6.69	7.00	4.28
BB-3	9.56	11.26	6.85	4.69
BB-4	5.61	2.39	2.64	4.55
BB-5	4.82	3.19	5.33	7.20
BB-6	3.12	2.56	5.04	3.03

MOLDING SAND TESTS.

Permeability to Air.

In order to determine the degree of porosity of a molding sand when rammed up into a mold, test blocks of 1 in. thickness, and 2 in. square, were included in the lot prepared as explained in the chapter on the Transverse Strength of Molding Sands. A given quantity of air was forced through these blocks under standard conditions, and the time noted.

The details of the test itself are as follows: Fig. 1 illustrates the apparatus as arranged for the test. The sand block is shown clamped in a frame, and connected with pressure system, the water descending from the upper jar into the lower empty one, drives one gallon of air through the tube and brass pipe of $\frac{1}{4}$ in. bore, into the sand block, the entire front of which is practically unobstructed, as the outer plate of the aluminum frame has a piece $1\frac{1}{2}$ in. in diameter cut out for that purpose. When the sand block is ready for clamping, the rear plate, with the $\frac{1}{4}$ in. diameter hole through which the air has to pass, is coated heavily with thick paint, so that the air may not escape along the surface—as for instance the blast along the lining of the cupola instead of all through the charge. The block is placed in position, the top plate put on and the whole clamped sufficiently tight to make a good job. The apparatus is now set a-going, the water running down first compresses the air in the lower jar and gradually forces it through the sand. When the one gallon of air has passed through, the test is stopped, the time noted, and the two jars reversed. The next test can then be made. Fig. 2 shows the clamp in better detail.

A number of trials were first made running these tests in blank—that is, without clamping any sand block for the air to pass through. It took just five minutes to allow the air to pass through the apparatus, the water in the upper jar descending into the lower to do so. The result of the tests are interesting, and show how slight the obstruction of the sand really is to the passage of air, or for that matter hot gases, for the additional

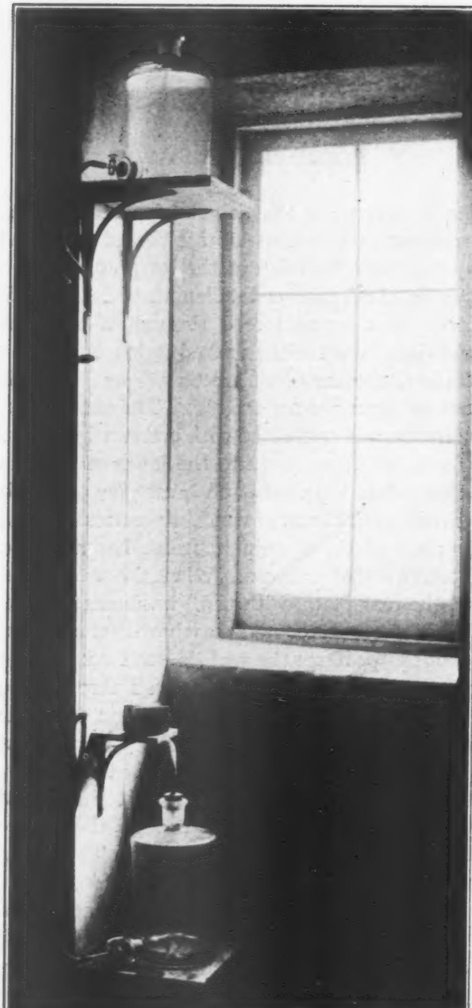


FIG. 1.

time taken ran from a quarter of a minute only, up to five, or double the blank test rate, with some exceptional cases of very wet sand.

The head of the water was 4 ft., corresponding to about 7 in. of molten metal, which is a pretty fair representation of the action of a riser in a mold. When it is calculated that a gallon of air, or 231 cu. in., has to pass through a tube $\frac{1}{4}$ in. in diameter in five

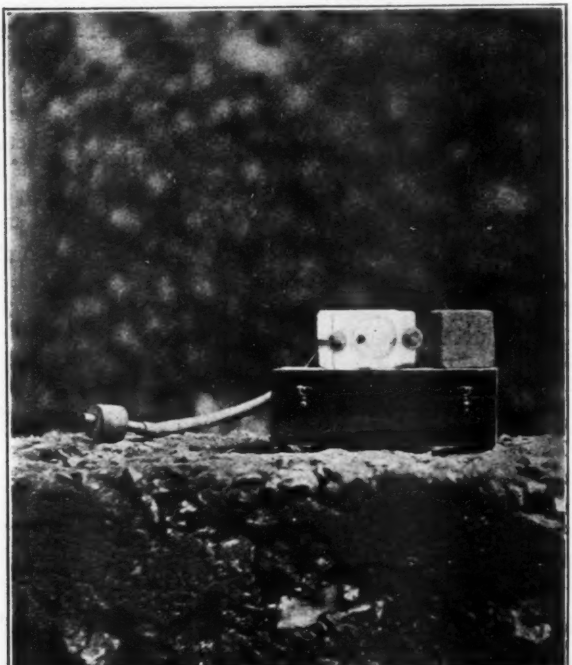


FIG. 2.

minutes, the rate—if this were a uniform one—would be about an inch a second in the unobstructed apparatus, very slightly less in the case of the open sands, and still half an inch a second in the dense cases. When a mold is being filled with molten metal the air in it will practically all escape through the risers and vents. Only that which would be entrained in the cope and insufficiently provided with means of escape would have to go through the sand.

Again, the sea-coal used for facing purposes when touched by the molten metal instantly gives off its volatile matter in form of a rich, tarry gas. This promotes a less intimate contact between sand and metal and gives a better finish to the casting. This gas, however, with any coming from the iron, must escape through the sand. Even with a rate of half an inch a second, it will be seen that there is no reason why these gases cannot get out of the mold in time before the metal sets. On the other hand, were the sand more compact or very wet, so that the rate of escape of the gases were reduced to say a tenth of an inch per second, it might happen that they could not leave through the mold fast enough, and would kick into the iron, leaving evidences of the metal not "laying to" the mold. It must be remembered that the test pieces were not rammed exceptionally hard, but rather the other way. With sands rich in clay and rammed too hard, the escape of gases and air from the cope would present a serious problem, and it is to be regretted that the useful little instrument devised by Mr. Thomas D. West, and described at the Indianapolis Convention of the American Foundrymen's Association (June, 1904) has not come into general use. By means of this device a molder can tell just how hard his sand has been rammed, and can gauge himself according to the sand used and the work in hand.

The results of this permeability test show that there is information to be gained by applying it to the several sands used in a foundry, when rammed soft and hard, and particularly the obstructing effect of too much water in tempering.

TABLE.—PERMEABILITY OF SANDS TO AIR.

The figures represent *Minutes* and fractions thereof required to drive 231 cu. in. (1 gal.) of air through a block of sand 1 in. thick, through a ¼ in. diameter orifice, over and above the time required for this air to pass through the apparatus unobstructed. The head is 4 ft. water.

Natural Molding Sands.

Mark	Dry	5 per cent water	7½ per cent water	10 per cent water
A-1	3	2	1½	1
B-1	¾	1	1¼	1¾
B-2	2¼	2½	2½	3½
B-3	¾	¾	¾	1

Mark	Dry	5 per cent water	7½ per cent water	10 per cent water
B-4	¼	2½	3	7½
B-5	3½	3¼	3½	9¾
B-6	¼	¾	¾	1
B-7	1½	1¼	1½	1¾
B-8	1	3½	3½	3¼
C-1	½	3	2¾	3¼
C-2	1¼	1¼	1¼	1½
C-3	½	¾	1	1
C-4	¾	¾	¾	1¼
C-5	¾	1	1	1½
C-6	1¼	1	1	1¼
D-1	1	½	1	1¼
D-2	¾	¼	¾	1
D-3	½	¼	½	½
E-1	¾	1¼	2¼	2¼
F-1	1¼	1	1½	1¾
F-2	1¾	1¼	1½	2¼
F-3	½	½	¾	1
F-4	1½	1	1	1¼
F-5	1	¾	¾	¾
F-6	½	½	¾	1
G-1	1¾	1½	1½	2
G-2	1½	¾	1	1½
G-3	1½	1½	1½	2
G-4	¾	1	1¼	1½
G-5	1	1¼	1¾	1¾
G-6	1	1¼	1½	1½
G-7	½	¾	1½	1¾
G-8	1	1	1¼	2½
H-1	1¼	2	2¼	2½
H-2	¾	¾	¾	1
H-3	1	1½	1	1
H-4	¾	1	¾	1
K-1	½	½	1	1½
L-1	¾	½	¾	1
L-2	1¼	½	1¼	1¾
L-3	1¾	½	¾	¾
L-4	1½	½	¾	¾

Mark	Dry	5 per cent water	7½ per cent water	10 per cent water
L-5	1¾	1¼	1½	1½
L-6	1	½	½	1
L-7	1¼	1½	1	1½
L-8	1	½	¾	1
L-9	1	½	½	1
L-10	½	¾	¾	1¼
M-1	¾	1¼	1¼	1½
M-2	¾	1	¾	¾
M-3	¾	½	¾	1
M-4	1	½	½	1
M-5	¾	¾	1	1¾
N-1	1	½	¾	¾
N-2	½	1	1½	2½
N-3	1	½	¾	½
O-1	1¼	½	¾	¾
O-2	1½	1	¾	1¼
O-3	1¾	½	¾	1
O-4	1	½	½	¾
P-1	¾	½	1	¾
P-2	1¼	¼	½	1
P-3	1¼	¾	1¼	1½
P-4	¾	1½	1¾	2½
P-5	1½	1	1¼	1½
R-1	1	1½	1¼	1¼
S-1	1½	2	2	2¼
T-1	1	1	1½	2
T-2	2¼	¾	1	3
U-1	2¼	2	3	6¼
U-2	2¼	1½	1	2
U-3	4½	1	3½	4¾
V-1	½	½	1½	3¼
W-1	4¾	1	4½	5
W-2	2	2¼	2¼	2½
W-3	¾	1	1	1
W-4	1½	½	¾	1

Mark	Dry	5 per cent water	7½ per cent water	10 per cent water
X-1	2	1	3¼	3¼
Y-1	2¾	3	4	5
Z-1	½	½	½	½
Artificial Molding Sands.				
AA-1	1	1¼	1½	1½
AA-2	½	2	2½	2¼
AA-3	1½	2½	2	2½
AA-4	1	1	1¾	1¾
AA-5	1	4½	4	4½
AA-6	1½	5	3½	4
BB-1	½	1	1½	1½
BB-2	¾	1¼	1¾	1½
BB-3	1¾	2	2¾	2½
BB-4	½	¾	½	½
BB-5	1	2½	2¼	1¾
BB-6	2½	2	2	2½

MOLDING SAND TESTS.

Clay Bond.

In the previous chapters the physical tests of molding sands tempered up with varying percentages of water have been gone into. These results when taken in connection with the rational analyses of the sands show non-concordant characteristics. That is, sands of the same fineness and clay percentage give widely different results.

An investigation was therefore made into the relative strength of bond in the series of molding sands, and this is based upon the adhesive quality of the clay contained. About the only and not entirely satisfactory method of determining the relative fatness or leanness of clays is their power to absorb dyes. The fatter the clay the more dye absorbed. The following method was adopted for the tests:

"Use 0.75 grammes of anilin green (malachite) dissolved in 250 c.c. water, shaking five minutes. Add 50 grammes of the molding sand and shake in machine for ten minutes, then pouring into a settling bottle. Let stand over night. Compare with standard solution of 0.75 grammes dye in 250 c.c. water, shaken and let stand in the same way."

In making this large series of tests, it was interesting to observe the variation in depth of color of the clear liquid above the sand and clay which had settled out. The strong sands could be detected immediately by the comparatively light blue-green color of the water in the upper part of the bottle, while in the case of the weak sands, it remained of almost full strength of color.

This colored water was put in one comparison tube and a measured quantity of the standard dye solution in another tube, side by side, and the latter diluted until the tints matched. The degree of dilution was then calculated and the percentage of dye absorbed determined.

In making the calculations to draw up the table of results

given below, the following example is cited. Case of A-1. This sand contained 26.80 per cent clay substance (see Chapter on Rational Analyses of Molding Sands), and as 50 grammes were taken for the test, the actual clay by weight would be 13.40 grammes. To this the 0.75 grammes anilin green was added. The subsequent comparison of tints indicated that the standard had to be diluted 16.1 times, showing that 6.21 per cent of the dye remained dissolved in the water, and the other 93.79 per cent had been absorbed by the clay in the molding sand. The 13.40 grammes of clay substance in the original 50 grammes of molding sand absorbing 93.79 per cent times 0.75 grammes of the dye, or 0.7034 grammes, this meant that every unit of clay in A-1 was capable of absorbing 0.7034 divided by 13.40, or 5.25 per cent its weight.

The table shows some very interesting things. In the case of the artificial sands, where 20, 30, and 40 per cent of fat and of lean clays were added to their complement of sharp and of round sands, the percentage of dye absorbed per unit of the clays is fairly regular, showing that the absorption test is quite reliable for a particular clay when the quantity of this may vary in the molding sand. There are some irregularities in comparing sands containing different clays, and that is the objectionable part of the test, as it is held by those who have done much work in this direction. There is, however, one point which may not have been considered as carefully as it should be, and that is the adhesion of the clay to the sand particles in comparing the strength of the molding sands, as shown by their transverse and crushing strengths, with the strength of the clay itself, as shown by the color absorption test. The molding sands U are examples of this. These sands were gathered by the Secretary from open pits some ten miles from his residence, the region happening to be the very one from which the fat clay for the artificial sand tests came—and this clay is one of the fattest and best in the country. The molding sands produced by nature from sea sand and this clay in prehistoric times, as shown by the physical tests given in the several tables, show up much better than the artificial sands made with the clay in question. This would seem to indicate that nature can do much better work than we can in distributing the clay substance in a molding sand, and that possibly our end of it is to sort the sands we have

and render their sizing more uniform. At any rate when adding clay or sand to a natural molding sand, it will be found best to do so a little at a time and to continually work it over by mechanical means, gradually getting a natural mixture.

The relative fatness and leanness of the clay portions in the molding sand series tested compare very favorably on the whole with the strengths as shown in the previous chapters, and may explain many seeming discrepancies.

TABLE.

Natural Molding Sands.

Mark.	Per cent clay substance.	Per cent dye absorbed.	Per cent dye absorbed per unit of clay in sand.
A-1	26.80	93.97	5.25
B-1	27.92	99.11	5.32
B-2	23.35	94.45	6.06
B-3	19.85	98.77	7.44
B-4	21.95	38.65	2.64
B-5	30.52	99.72	4.90
B-6	28.10	98.35	5.26
B-7	28.75	99.87	5.20
B-8	21.70	94.47	6.41
C-1	25.33	61.69	3.64
C-2	20.90	96.91	6.96
C-3	23.76	98.91	6.18
C-4	21.44	98.08	6.86
C-5	18.05	83.53	6.94
C-6	19.44	96.24	7.44
D-1	21.60	41.52	2.88
D-2	15.50	29.03	2.82
D-3	13.80	33.34	3.62
E-1	18.99	32.89	2.58
F-1	16.92	44.45	3.94
F-2	14.15	43.50	4.60
F-3	18.89	43.18	3.42
F-4	20.17	43.18	3.30
F-5	21.35	43.18	3.02
F-6	24.23	43.18	2.68

Mark.	Per cent clay substance.	Per cent dye absorbed.	Per cent dye absorbed per unit of clay in sand.
G-1	25.24	94.45	5.62
G-2	21.36	41.48	2.90
G-3	18.08	98.98	7.78
G-4	25.95	98.61	5.70
G-5	18.60	98.34	7.92
G-6	26.27	99.87	5.70
G-7	18.65	95.12	7.64
G-8	32.19	98.78	4.60
H-1	20.17	57.45	4.26
H-2	18.28	46.25	3.90
H-3	17.37	90.57	7.94
H-4	17.99	95.42	7.96
K-1	13.38	38.65	4.33
L-1	13.68	39.76	4.36
L-2	17.70	50.00	4.23
L-3	14.40	29.37	3.06
L-4	14.19	31.00	3.28
L-5	18.94	46.81	3.71
L-6	22.77	39.76	2.62
L-7	22.57	39.76	2.64
L-8	24.87	39.76	2.40
L-9	20.33	39.76	2.93
L-10	27.90	39.76	2.14
M-1	18.85	47.37	3.77
M-2	20.36	47.09	3.47
M-3	18.16	47.09	3.88
M-4	22.10	47.37	3.21
M-5	19.35	50.00	3.87
N-1	41.20	99.14	3.61
N-2	30.25	92.58	4.59
N-3	32.54	99.15	4.47
O-1	16.68	19.20	1.72
O-2	17.10	19.20	1.68
O-3	20.08	42.86	3.40
O-4	19.17	87.01	6.81
P-1	29.80	98.29	4.94
P-2	23.30	95.00	6.11

Mark.	Per cent clay substance.	Per cent dye absorbed.	Per cent dye absorbed per unit of clay in sand.
P-3	19.68	59.02	4.49
P-4	21.40	59.35	4.17
P-5	24.78	92.58	5.20
R-1	26.44	99.67	5.65
S-1	26.28	56.71	3.23
T-1	27.50	98.92	5.39
T-2	29.78	99.18	4.99
U-1	8.85	52.38	8.88
U-2	15.45	69.42	6.74
U-3	13.67	59.35	6.44
V-1	16.65	98.68	8.89
W-1	28.10	74.36	3.97
W-2	26.82	90.74	5.08
W-3	18.37	74.36	6.07
W-4	25.85	60.32	3.50
X-1	17.94	59.35	4.96
Y-1	21.11	91.93	6.53
Z-1	23.99	95.00	5.94
Artificial Molding Sands.			
AA-1	16.59	47.37	4.28
AA-2	24.89	92.23	5.56
AA-3	33.19	92.61	4.18
AA-4	18.14	37.50	3.10
AA-5	27.21	62.96	3.48
AA-6	36.28	69.79	2.88
BB-1	16.59	44.45	4.02
BB-2	24.89	97.61	5.92
BB-3	33.19	97.88	4.42
BB-4	18.14	45.95	3.78
BB-5	27.21	58.34	3.22
BB-6	36.28	71.43	2.96

MYSTERY VERSUS CHEMISTRY IN GRADING PIG METAL.

By Thos. D. West, Cleveland, O.

One would hardly think that in these days of foundry enlightenment grading by fracture is still advocated, but that such is still the case is indicated by a recent publication, as well as the disinclination of a national Foundrymen's Association in Europe to go on record as abandoning grading by fracture in favor of purchasing pig iron by analysis only. Were not such advocacy a distinct step backward, in that it scares off the foundryman just ready to adopt the advanced method of handling his metallurgical problems, it would be a sheer waste of time to discuss the question at all; for the man never lived, or is alive to-day, who can reliably define by the fracture of the pig metal of our current brands the grade of the casting this will produce, when remelted. Any attempt to do this is the merest guess-work.

On one point for example—were grading by fracture reliable—would we have to revise our present conception, and that is the effect of the rate of cooling, so far as it influences the formation of a chill, and the size and structure of the crystals in grey iron castings.

In the old days, when fracture grading was in vogue, and the predictions made did not come true, it was laid to a mistake in taking iron from the wrong pile in the yard, or the coke might have been exceptionally dirty. Hard iron or steel might have been mixed with the scrap, the charges badly mixed or laid on uneven. Then again the coke might have been too soft for that pig iron, or the blast not strong enough, or even too much. A damp atmosphere, too small a bull-ladle; iron right, but molds wrong. In short anything but the wrong guess in fracture grading. Even to-day there is added in such cases the possible excuse of high sulphur in the coke.

One of the best opportunities to test out the grading by fracture delusion may be had at the present time around many of our

blast furnaces. Here are oftentimes big tonnages of unsalable iron, piled nicely showing the fracture, and all properly analyzed. Any advocate of grading by fracture can make his guesses without restriction. This brings to mind an incident occurring about in 1894, while the writer was in the midst of his combat against grading by fracture and advocating working by analysis only. A good friend and old-time expert furnaceman was belittling chemistry and claimed that he could judge any iron by its fracture. Knowing that there had been some errors made in his records of analyses of several thousand tons of pig iron then at this furnaceman's yard, and also that all the piles on being re-analyzed had had the numbered samples placed into one pile of about ten tons, the writer challenged his friend to determine the grade of a large number of these samples by his fracture experience. This challenge was readily accepted, and the expert started in to guess of each sample, as it was handed him, whether it would produce a soft, medium or hard iron in a $\frac{3}{8}$-in. thick casting, on being remelted. An assistant recorded the predictions carefully. When compared with analyses they indicated that less than one-third of the guesses would have proven correct, and while the furnaceman had previously readily admitted that the composition of a pig iron regulated the resulting casting in the main, he was so filled up with reasons for unexpected results that he had never thought of giving himself the test the writer had done.

As was but natural many foundrymen were unable to use chemistry intelligently in the early days, and this is eagerly grasped by those who do not wish to inform themselves upon the why and wherefore of the change. One of the most striking situations proving that the use of chemistry in the foundry can enable rapid fracture tests of the resulting molten iron to be made with remarkable success is seen in the car wheel works. Without purchasing their pig iron and mixing it by analysis, it would not be possible to get the remarkable uniformity in the little chill blocks cast every tap, let stand five minutes or so after solidifying, plunging into water and breaking to display the fracture. These blocks, some 2 in. by $2\frac{1}{2}$ in. by about 8 in. long, with one side chilled to show the character of the metal as it would be found in the chilled part of the wheel, can be made to show an almost perfect uniformity day in and day out. This is only possible

when analysis is used to base the work upon. Considering that wheel foundries make from 200 up to 1,000 wheels per day, and that the inspection and tests are most rigid—human life depending upon their integrity—the certainty arising from knowing exactly what went into the cupola is vastly preferable to the mystery of the fracture expert.

From 1892 to 1905 the writer was shop manager of a foundry melting 100 to 150 tons of metal daily, most of which went into a specialty as exacting for uniformity of material as any car wheel shop. A specific brand of iron was required, being delivered in cars and by buggies from a neighboring furnace. In the early days the cupola man would oftentimes object to the delivery because of white and spongy fractures exhibited by broken pigs. Proximity to the furnace allowed close tab to be had on their burden, and if no change had been made in ores or coke, these suspicious casts were simply held up until an analysis showed whether they were of the desired composition or not. If so, in they went. Formerly such iron would not have been received. The resulting castings always showed the nice grey open fracture desired in them. The cupola man, by the way, was soon brought to accustom himself to the changed conditions, and so long as he knew of no change in the furnace operation—which he was able to check also—he was quite content.

Judging brands and grades of pig iron are two different propositions. We can readily tell a charcoal pig from the coke. But as between two foundry irons or Bessemer irons, it is difficult to tell two brands apart. In fact it is practically impossible to do so. A change in the ores used by a furnace really creates a new brand, and even with the same analyses, two irons from the same furnace, made of different ores are apt to give different results when remelted.

The only proper physical test of quality in pig irons, is to remelt them and cast test bars of standard size and under standard conditions. With this knowledge, and the comparison of other such tests of brands, the founder is reasonably safe to go ahead with a new brand. Why those who claim the ability to define the grades of brands have not also claimed the same for changes in these brands, can only be attributed to the fact that their grandfathers have not handed this claim down to them. It would have been just so much more mystery and guessing.

THE ECONOMIC SIDE OF THE TWELVE-HOUR SHIFT IN THE STEEL FOUNDRY.

By R. A. Bull, Granite City, Ill.

It will doubtless be granted that, on account of recent agitation concerning the long hours of employment almost universally obtaining in certain departments of steel works and blast furnaces in the United States, a frank discussion of this question in the sessions of this Association, whose membership includes many steel founders who employ the 12-hour shift on their furnace platforms, is in order at this particular time. You are aware of the public attention now being given to this question, partly through articles which have appeared in the popular magazines, and more especially because of congressional inquiry. Certain leaders in the world of iron and steel have lately testified before the Senate committee concerning the necessities for continuous operation of steel and blast furnaces requiring attention of attendants for every hour of the day for every day of the week, and have endeavored to describe the nature of the duties devolving upon these men. I am frank to say that the testimony given upon the latter point by some captains of industry has amused me, as it doubtless has many others, by its mis-statement of facts, possibly due to incorrect knowledge of working conditions.

As employers of labor, we must look this question squarely in the face, realizing, if we do not understand as well as a layman may, the nature of work we require of men for twelve hours per day for seven days of the week, it is high time that we fully inform ourselves, and further, that having ascertained those facts, we will by no means benefit ourselves by attempting to disguise conditions.

The question of the long shift, so far as the American Foundrymen's Association is concerned, crystallizes into a consideration of the melter and his furnace helpers, and has to do with the steel foundry. I assume it to be unnecessary to set forth in any sort of detail the nature of the steel-maker's occupation, to those

members of this Association who are engaged in the manufacture of steel castings. Briefly, however, for the benefit of all others who may be interested in the subject, the work is distinctly arduous, physically and mentally, carries a responsibility which puts a man's nervous system in frequent high tension, and is especially trying on the physical system during the summer months. It can, however, be truthfully stated that the difficulties of the work are not constant but periodic, also that the Sunday shift in the steel foundry (not necessarily in the steel mill) is a very easy one. A furnaceman may have a considerable interval of comparative relaxation, when his furnace and heat respond nicely to his manipulation, and weather conditions prevail which do not make the working temperature a hardship. And again he may, in spite of all the experience and skill at his command, have about as trying and exhaustive a day's work, without intermission and for several days in succession, as one can readily imagine. This latter fact being admitted, one can understand why our legislators are putting the furnaceman's occupation under scrutiny, in the interest of humanity. It may be claimed, and with some degree of truth in certain instances, possibly, that *all* of this interest has not been stimulated by humane motives, but for political reasons. But disregarding the ulterior motives of the ever-present demagogue, and analyzing this question conservatively, it must be apparent to us that a few more years *may* see legislation honestly conceived that will put an end to the twelve-hour shift for the steel-maker.

This paper does not purport to deal with the humanitarian side of the issue. But without stating in brief my own convictions it might be claimed that I evade that phase of the question. Not wishing to invite such a criticism, at the risk of being superficially regarded as voicing an opinion, which, if maintained by those of greater influence than myself, should be cried down as inimical to large and important iron and steel interests, I do not hesitate to state my belief in the absolute injustice, humanely speaking, of the twelve-hour shift on the furnace platform. I trust that I shall not be classified as a Socialist for having such a conviction. The question must be decided neither from the view-point of the plutocrat nor that of the walking delegate, and I claim to have formed my conclusions after consideration of the question from a conservative standpoint, and after many

years of personal observation of working conditions surrounding the furnaceman's work. Furthermore, to offset any suggestion of bias, let me say that I do not now hold, and never have held, a union card, active or honorary, issued by any labor organization.

The company with which I am associated some time ago inaugurated three eight-hour shifts as applying to the furnace and boiler crews, both of which had previously worked twelve-hour turns. It had been my opinion, and that of my immediate superior, that such a revision of our working schedules in these departments would be accompanied with so much more efficient handling of the furnaces that if the rates per hour were reasonably increased to remove the natural disinclination of the men to receiving only two-thirds of their former monthly income, the final result would show economy. This was the purely business side of the question, whose humanitarian aspects received our first consideration. A careful adjustment of wages was planned which yielded an increase per hour of 22 per cent to the first-helpers, 18 per cent to the second-helpers, and 16 per cent to the third-helpers. Even the door-boy was included in the scheme, and was to receive an advance of 19 per cent per hour. The boiler fireman were to be increased 19 per cent per hour, and the coal-passers 14 per cent. It should be borne in mind that none of the men affected had asked for a change in the shift-hours, or an increase of wages, nor had any plant in our vicinity any such change in contemplation.

Permission of our principal executive officers was obtained to inaugurate the new plan, and when it was put into effect, it came as a glad surprise to the various crews. No inducements were offered them to render more efficient service, nor was any suggestion made that we proposed to keep comparative data. But it was an easy matter to make comparisons because we had a meter registering within one-half of one per cent of accuracy by careful test, on each open-hearth furnace line to record the fuel oil consumption, a magnetic recorder to indicate the frequency with which the furnace burners were reversed, a system by means of which all extra pig iron used in each heat was weighed and recorded, a recording pressure gage to show the steam pressure maintained in the boiler room, and finally the chemical analyses and physical tests customarily made for every heat to determine the relative qualities of the product.

Before studying the comparative record, permit me to state for your more intelligent consideration of the various showings, a few important facts. The first four weeks prior to the change, and the first four weeks following, were taken as those best for comparison, because working conditions for these two periods were as nearly identical as could readily be found in our plant. The melting stock, the fuel oil, and the boiler coal were of uniform quality throughout, so far as the same grades or brands of these materials may possibly be. The demand made upon each 250 H. P. boiler under fire was practically the same in each case, the air load being steady, but the electrical load extremely intermittent for the entire eight weeks, a chronic condition which in our case militates greatly against a desired uniformity of 125 lbs. of steam pressure. The practice on the open-hearth platform had obtained for years of reversing the burners every twenty minutes when a furnace was charged, and every thirty minutes when empty. It was of course the object to make the least possible additions to the percentage of pig iron charged, and the furnacemen were required to exercise such judgment in this respect as would keep the amount of extra pig within reasonable bounds, and as low as possible. Naturally they were also expected to keep the burners nicely adjusted and to maintain the proper temperature of the bath at the lowest possible oil consumption. The furnaces were basic, and 47,000 lbs. of metal was charged per heat. The shift hours under the old plan had been from six to six; under the new arrangement they are from 7 A. M. to 3 P. M., 3 P. M. to 11 P. M., and 11 P. M. to 7 A. M., these being the most convenient because of local conditions. The crews change their shifts the first day of each week, thus giving every three weeks, the full daylight turn to each crew. Having made the above points clear, I refer you to the comparative record, on which you will find certain results not shown as actually found, but indicated in a fashion sufficient for ready comprehension.

It will be readily understood that we were greatly gratified at the comparison, which indicates fully a more economical and efficient manipulation of both open-hearth and boiler furnaces. It will be observed that the differences in most cases are slight, but the pleasing and important feature is that the essential ones are in favor of the short shift. If we had had suitable means of

weighing our coal as it was stoked, we could have elaborated our boiler-room records, for we had on our boiler line a water meter, and on our feed-water heater a thermometer, to indicate the evaporation. But we did not have at hand convenient facilities for exactly determining our coal consumption.

It was not to be expected that the greatest improvement would take place immediately after the change, and had all working conditions been some months afterwards practically the same as they were previous to the adoption of the eight-hour shift, there could have been made a fairer comparison. Certain important working conditions having changed, it was advisable to compare periods as indicated. But it is interesting to know that in those instances where conditions remained constant there was a noticeable improvement the second month as compared with the first month after the new schedule was in force, as, for example, the reduction in the average amount of extra pig iron charged per heat, from 424 lbs. to 137 lbs.

I do not know if any such comparisons as those made the basis of this paper have heretofore been made in a similar fashion. It is quite possible that the idea has some degree of novelty in certain of its details, for, notwithstanding the criticisms recently directed against the twelve-hour shift, its prevalence is still almost universal in furnace operation in this country. And I feel satisfied that any careful comparison along the lines indicated by the record herein shown would convince any steel manufacturer of the wisdom of operating with three eight-hour shifts, purely from an economic standpoint. Speaking for the people with whom I am associated, we are greatly pleased over the change. And I can speak for the men in the same terms, for our furnacemen are enthusiastic in their praise concerning the new plan. And there is no small amount of inward satisfaction in the knowledge that we have done a humane thing. I have felt that you ought to know about it, and I have believed that once having the knowledge in your possession at least some of you would fall in line of your own free will, and with better grace than will be possible when in the future you may find yourselves required by statute to discontinue your present schedules of working hours. It may be argued that, while the demands of humanity and economy are admittedly strong on the furnace platform, in favor of the eight-

hour shift, its adoption is unwise there because of the effect it might have upon workmen in other departments, where the nine- or ten-hour day is at present prevailing, and where conditions would not commercially permit the universal eight-hour day. But conditions in a steel foundry cannot be found in any other department that are at all similar to those found around the furnaces, and that fact is apparent to molder, pattern-maker, core-maker, machinist, electrician, or any other mechanic. Any argument which can be so readily met must fall, and its best answer is found in the fact that its adoption in the plant whose experiences have in a way been here described, has resulted in no tendency towards the demand for an eight-hour day among any of the skilled trades represented in our organization, after the lapse of sufficient time to make such a movement at all probable as a result of the precedent.

Therefore, viewed from any conceivable angle, I claim the change is justifiable, and you will do well to make it, so far as your open-hearth furnaces are concerned. As to your boiler firemen, each operating head must decide for himself. In our particular case it appeared to be, and finally proved to be, advisable from every standpoint. Conditions in certain other boiler rooms are very different from ours, practically the entire evaporation taking place during the daylight hours in many of them. Since the results are of some interest, however, I have included the comparisons made in our power plant. Reverting finally to consideration of the steel-maker, whose performance under both schedules is made the burden of this argument, the basic principal is absolutely sound, and rests on the incontrovertible fact that you cannot expect any man to give you the best that is in him when you keep him employed without intermission for twelve hours per day, seven days per week, at work making a heavy demand upon his mental and physical powers, under conditions of high temperature such as obtain on a furnace floor. To expect the best results under such circumstances is folly, and to continue operating under them spells, not the title of this paper, but the *costly* side of the twelve-hour shift.

OPEN-HEARTH FURNACES.

		Twelve-hour Shift.	Eight-hour Shift.
Average amount of extra pig iron charged per heat		556 lbs.	424 lbs.
Average amount of fuel oil consumed per heat		1,275 gals.	1,138 gals.
Average amount of fuel oil consumed per ton of metal charged		55 gals.	49 gals.
Average number of cracked castings per heat		.49 gals.	.37 gals.
Average of longest intervals between reversals of burners during 12-hour periods		28 min.	26.7 min.
Average of chemical analyses of all heats	Carbon	Correct percentage	Correct percentage
	Phosphorus	.011%	.011%
	Sulphur	.022%	.022%
	Manganese	2 points under	Correct percentage
	Silicon	1 point over	Correct percentage
Maximum phosphorus in any heat		.022%	.018%
Maximum sulphur in any heat		.025%	.025%
Average physical tests of all heats	Yield point per sq. in.	13.0% over	15.5% over
	Tensile strength per sq. in.	5.9% over	5.8% over
	Elongation in 2 in.	4.6 points over	4.1 points over
	Reduction of area	7.9 points over	7.2 points over
Minimum physicial tests of any heat. (Not combined results of one bar, but individual minimums of results covering all bars.)	Yield point per sq. in.	2.5% under	7.7% over
	Tensile strength per sq. in.	4.7% under	1.4% under
	Elongation in 2 in.	5 points under	3 points under
	Reduction of area	8.3 points under	7.6 points under

The term "point" means a hundredth of one per cent where analyses are referred to, and elsewhere one per cent, but in all cases it refers to differences from works standard, being found by simple subtraction. In no case does it indicate relative or proportionate results. Where such are shown they are indicated by "per cent" followed by "over" or "under." "Over" and "under" mean respectively results more or less than those desired by plant requirements, and we have no reference to A S T M standard specifications, the requirements of which are fully met in all the minimum results obtained under the eight-hour shift. "Correct percentage" means exactly the composition desired. Lowest possible content of phosphorus and sulphur demanded by plant requirements.

BOILER ROOM.

	Twelve-hour Shift.	Eight-hour Shift.
Number of times when steam pressure fell below 110 lbs.	77	42
Number of times when steam pressure fell below 105 lbs.	9	3
Number of times when steam pressure fell below 100 lbs.	1	0

Operating expense for Boiler Room Labor. On 12-hour shifts, from 6 A. M. to 6 P. M., one head fireman, two second firemen and two coal passers were employed; and from 6 P. M. to 6 A. M one head fireman, one second fireman and one coal passer, at total expense per day of 24 hours of $19.50. On 8-hour shifts, from 7 A. M. to 3 P. M., one head fireman, one second fireman and two coal passers were employed; and on each of the other two shifts one head fireman, one second fireman and one coal passer were employed, at a total expense per day of 24 hours of $19.12, or 38 cents less per day of 24 hours divided into three 8-hour shifts, despite the increased wages per hour.

NOTES ON CLOSE-GRAINED SOFT CAST IRON.

By John Jermain Porter, Staunton, Va.

To most users of castings cast iron is simply cast iron and a casting is satisfactory as long as it is true to pattern, free from shrinkage and gas holes, and soft enough to machine readily. There is, however, a growing demand for cast iron of special properties, and users are becoming educated to the point of demanding castings not only outwardly perfect, but also of material exactly suited to their needs.

A case in point is the demand among machinery builders, and especially the machine tool people, for castings close grained and capable of taking a high polish, and at the same time soft and easily machined. It is surprising what a difference is made in the appearance of the finished machine by the iron used, particularly after it has been in use a short time. An open-grained iron when polished presents a dull gray surface marred by a multitude of little hair lines, due to the rubbing out of the large graphite flakes. On the other hand a close-grained iron polishes to a white steely surface, very pleasing to the eye, and free from graphite lines except on very close inspection. After a machine has been in service a while these differences are accentuated, since the open-grained iron absorbs oil and dirt and becomes darker, while the close-grained iron by simply wiping off is restored to its original whiteness.

Machine tool builders take great pains with the appearance of their product and use polished surfaces very freely. At the same time they are not as a rule willing to sacrifice cheapness of production as represented by ease of machining. Hence the demand has been loud and insistent for the combination of close grain and softness, and in some cases such castings will command considerably higher prices.

We are accustomed to think of these two properties as being incompatible. To a certain extent this is true, the closest grain

going with a very hard iron, but it is also true that for any given degree of hardness there is a wide range in the possible grain structure. The subject is a rather difficult one to study, largely because of the lack of means for definitely measuring and recording grain size. Very little is known as to the real cause of differences in grain structure, and the following notes are presented, not as a complete exposition of the subject but as summarizing present knowledge, and in the hope of arousing more general interest.

The controlling factor in grain size is no doubt the size of the flakes of graphite, their distribution and number. Other subordinate factors if any are obscure and poorly understood. The whiteness of iron as shown on its polished surface is not strictly in proportion to its closeness of grain, but as a general rule the two things go together. A desirable iron must, therefore, have a limited amount of graphite, in small flakes and uniformly distributed.

Coming now to practical means of controlling graphite, grain size and hardness, I have classified these under the following heads:

1. Chemical composition.
2. Use of steel scrap, chips, etc.
3. Selection of kind of iron and brands.
4. Use of alloys.
5. Control of rate of cooling.
6. Cupola practice.
7. Practice in machining.

Chemical Composition.

The most important element is silicon, which should be kept just as low as possible without hardening the iron too much. Most foundrymen carry an excess of silicon in order to be on the safe side in the matter of hardness, and this can usually be considerably cut down provided the mixture is under close chemical control.

Sulphur will close the grain if in excessive amount, but only at the cost of hardness and probably other troubles. Personally I do not consider it a safe means to use.

Manganese is ordinarily supposed to have an important influence in closing grain, but I am rather doubtful as to its efficiency. In moderate amounts it probably has some good effect, but an excessive quantity will not only harden, but may actually open the grain, due to the formation of large crystals of manganese carbide.

Phosphorus, within the usual limits, probably has little or no effect on either grain size or hardness.

Use of Steel or Chips in the Mixture.

The use of steel scrap and the making of the so-called semi-steel is becoming very common, and where properly handled it is a very excellent means of closing grain and increasing strength. Ten to 25 per cent is generally used, and if silicon is properly regulated the hardness will not be materially increased. Of course the good effects of steel may be nullified by cupola troubles incidental to its use, and the necessity of special precautions when charging it is now generally recognized.

The addition of chips to the charge also has a strong tendency to close the grain, but in this case again precautions must be taken to avoid oxidation and cupola troubles. It is very difficult to understand thoroughly the action of steel and chips in closing the grain. In part it is no doubt due to decrease in the amount of carbon (and graphite) in the casting, but it cannot be all attributed to this cause as in many cases analyses show the close-grained iron to be quite high in carbon, due, of course, to absorption in the cupola.

Selection of Kind of Iron and Brand.

Charcoal iron, if properly used, will give much closer-grained castings than coke iron of equal hardness. There is also a considerable difference in the behavior of different irons of the same class, some brands giving better results than others.* Apparently the difference is due to variations in furnace practice and materials used, but no definite rules can be given and the best brands can only be found by experience.

---

* See also paper by the present writer entitled "Peculiar Properties of Pig Iron," read before The Pittsburgh Foundrymen's Association and printed in the *Foundry* of December, 1911.

Use of Alloys.

The sellers of certain foundry alloys claim among other things that their addition will close the grain. I have experimented somewhat along this line but without getting any very marked results. The use of either titanium or vanadium alloy seemed to give more uniform and possibly a little closer grain structure, but these results would probably have been more pronounced on a poorer grade of iron.

Control of Rate of Cooling.

It is well known that rapid cooling gives smaller grain size and greater hardness. It is common practice to use chills to form the Vees of lathe beds, the size of the chills being so proportioned as to decidedly close the grain and yet not actually chill the iron and make it very difficult or impossible to machine. Cores are also used in some cases where they are not otherwise necessary on account of their cooling power and to close the grain.

Within recent years it has been discovered that cast iron may be made close grained by cooling rapidly through its solidifying temperature and just below, and at the same time soft by cooling slowly through the lower range. This principle is applied in Custer's process of casting in permanent molds. Castings can be made considerably softer by allowing them to remain in the sand until cold and thus anneal themselves. Since slow cooling through the lower range of temperature probably does not effect the grain size, it follows that a combination of low silicon and prolonged cooling is useful in getting the desired properties of softness and close grain.

Cupola Practice.

Bad cupola work is capable of nullifying the effects of almost all of the methods suggested for reducing grain size. It may also produce close grain in combination with hardness through excessive oxidation. It is thought by some that the rate of blowing and blast pressure have a good deal to do with the grain structure of the iron, and it is certainly true that the height of the melting zone and coke bed is, in some cases at least, an important factor. The higher the melting zone and the longer the column of coke through which the iron trickles the greater the tendency to open grain.

Practice in Machining.

It is known to most machinists, but not to all foundrymen, that a good close-grained iron can be made to appear open grained by machining. A heavy roughing cut will pull and tear the iron crystals and for a short distance below the surface produce a very open structure. If now the finishing cut is very light, or if the finish follows directly on the roughing cut the iron will appear very open grained, while with proper treatment it may be entirely satisfactory.

I have purposely avoided going into theory in this paper, but to those who are interested in reasons why I recommend a recent paper by E. Adamson.* In this paper evidence is given to show that several forms of graphite exist, varying considerably in their behavior during the melting and solidification of the iron. In my opinion this fact is competent to explain most of the differences existing between coke and charcoal pig and between different brands of iron, as well as some of the peculiar effects of steel scrap in the cupola.

* "Temperature Influences on Iron and Carbon," *Jour. Iron and Steel Inst.*, No. 11, 1911.

REPORT OF THE COMMITTEE ON STANDARD METHODS FOR DETERMINING THE CONSTITUENTS OF FOUNDRY COKE.

SAMPLING.

Each carload of coke shall be considered as a unit. While the car is being unloaded, full length pieces of coke shall be taken at about equal intervals and a sample approximately the size of an egg taken from each end and also from the middle of each piece, until 25 to 40 pounds are obtained. Should it be necessary to sample from a stock pile, 25 to 30 pounds of sample, obtained as above directed, shall be taken for each fifty tons in the pile, care being used to get the piece from different places which will give a fair average sample.

PREPARING THE SAMPLE.

Crush the sample between hardened surfaces, preferably of manganese or chrome steel, until all the material passes through a ½-inch mesh sieve. Quarter this; reserve one portion for moisture determination and crush the other portion until it will all pass through a ¼-inch mesh sieve, and again quarter down until about two pounds remain. Crush this until it will pass a No. 20 mesh sieve, and quarter down to about 20 grams. Grind this until it all passes through a No. 100 mesh sieve.

MOISTURE.

Dry one kilogram of ½-inch mesh sample to constant weight at 104° to 107° C. The loss in weight shall be calculated to per cent moisture. Moisture shall be determined on the ground sample by getting the loss in weight when one gram sample is heated in an open platinum crucible of about 20 cubic centimeters' capacity for one hour at 104° to 107° C. The moisture on the ground sample shall be used to calculate the other results gotten from the ground sample to percentages in the coarse undried sample.

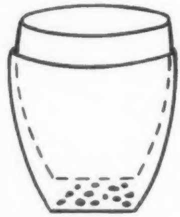
Volatile Matter.

Cover the crucible containing the dried sample, with another crucible (either platinum or porcelain) of such a size that it will fit closely to the sides of the outer crucible, and its bottom will rest one-third ($^1/_3$) to one-half ($\frac{1}{2}$) inch above the bottom of the outer crucible.

Ignite $3\frac{1}{2}$ minutes with the Bunsen burner and $3\frac{1}{2}$ minutes with the blast lamp. Let cool, remove the inner crucible and reweigh the outer crucible with contents. The loss of weight is volatile matter.

Ash and Fixed Carbon.

Ignite the sample upon which the volatile matter was determined until all the carbon is burned, having the crucible open



and inclined. The ash should be tested for unburned carbon by moistening it with alcohol, which will show black any carbon remaining. After all carbon is burned, the weight of the crucible and ash minus the weight of the crucible, gives the amount of ash in the sample.

The amount of fixed carbon is obtained by subtracting the weight of the crucible and ash from the weight of the crucible and residue from the volatile matter determinations.

Sulphur.

Crucible.—A soft steel or nickel crucible of about 40 cubic centimeters' capacity, the lid being perforated with a small hole for the introduction of the igniting wire.

Crucible Stand.—Any arrangement suitable for holding the crucible firmly in place and out of contact with the beaker during the peroxide combustion.

Determination.—To the dry crucible add first 12 grams of sodium peroxide and 0.5 gram of powdered potassium chlorate, then exactly 0.7 gram of coke (80 mesh) and mix thoroughly by means of a small spatula. Place the covered crucible on its stand in a 20-ounce beaker containing enough water to immerse the lower half of the crucible.

Ignite the crucible contents by thrusting in, for a moment, a red hot wire through the lid hole. Wait two minutes or longer for the mass to cool somewhat, remove the stand and tip over the crucible on its side in the water. After the fusion dissolves, rinse and remove the crucible.

Acidify the solution with hydrochloric acid, then add ammonia in slight excess, filter and wash. To the filtrate add a drop of methyl orange, then hydrochloric acid from a graduated pipette or burette until 0.5 cubic centimeter in excess. Bring to boiling, add drop wise about 10 cubic centimeters of barium chloride solution, continue boiling at least fifteen minutes longer, and allow it to stand in a warm place for not less than two hours, filter, wash until the silver nitrate test shows no chlorides, ignite and weigh as $BaSO_4$.

$$\text{Grams } BaSO_4 \times 19.6 = \% \text{ Sulphur.}$$

Phosphorus.

Ignite 5 grams of coke in a platinum dish or large platinum crucible until all the carbon is burned off, then add 10 cubic centimeters hydrochloric acid (1-1) and 20 cubic centimeters hydrofluoric acid and evaporate to dryness and ignite at a dull red heat. Fuse the residue with about 1½ grams of sodium carbonate and 2 grams of potassium nitrate. Cool, place the dish in a beaker of water and boil. Clean and remove the dish. Acidify the solution with hydrochloric acid, precipitate with ammonia, boil, filter and wash with hot water. Wash the filter with warm dilute nitric acid to dissolve the precipitate. Should it not dissolve, wash with warm dilute hydrochloric acid until dissolved. In the latter case, it will be necessary to evaporate to about 5 cubic centimeters, add 30 cubic centimeters nitric acid (1.20 sp. gr.); again evaporate to about 5 cubic centimeters and add 30 cubic centimeters nitric acid (1.20 sp. gr.). After

heating the solution to between 70° and 90° C., add 50 cubic centimeters of molybdate solution. Agitate the solution a few minutes, then filter, and wash five times with a 3 per cent nitric acid solution, and five times with a 0.1 per cent potassium nitrate solution. Transfer the precipitate and filter to the flask in which the precipitate was made. Add 30 cubic centimeters water, then *NaOH* (*N*-5) from a burette until in excess, keeping the solution agitated. When the yellow precipitate is all dissolved add 0.1 cubic centimeter of phenolphthalein solution as indicator, and then titrate with H_2SO_4(*N*-5).

c.c.(*N*-5) *NaOH* = c.c. (*N*-5) H_2SO_4 x .0054 = % Phosphorus.

To make the molybdate solution, add 100 grams molybdic acid to 250 cubic centimeters water, and to this add 150 cubic centimeters ammonia. Stir until all is dissolved and add 65 cubic centimeters nitric acid (1.42 sp. gr.). Make another solution by adding 400 cubic centimeters concentrated nitric acid to 1,100 cubic centimeters water, and when the solutions are cool, pour the first slowly into the second with constant stirring and add a couple of drops of ammonimum phosphate.

DR. ANDREW A. BLAIR,
HERBERT E. FIELD,
J. O. HANDY,
A. P. FORD,
FROEHLING & ROBERTSON,
J. R. HARRIS,
DR. L. C. JONES,
PROF. THOS. B. STILLMAN,
WARREN J. KEELER,
H. C. LOUDENBECK,
HENRY SOUTHER,
R. S. MACPHERRAN,
H. E. DILLER, *Secretary*,
Committee.

AMERICAN FOUNDRYMEN'S ASSOCIATION.

THE EDUCATION OF APPRENTICES IN THE FOUNDRY.

By Dr. Otto Brandt, Secretary German Foundrymen's Association.

Memorandum by P. Kreuzpointner, Chairman A.F.A., Committee on Industrial Education.

Dr. Otto Brandt, General Secretary of the German Foundrymen's Association, with offices at Düsseldorf, Germany, has been delegated by the Chamber of Commerce of that city to represent it at the meeting of the International Association of Chambers of Commerce, to be held in Boston during the latter part of September. Owing to the practical coincidence of this meeting with that of the Foundrymen's Association at Buffalo, it may be impossible for him to favor the Foundrymen with his presence. However, although the members, while meeting in convention at Buffalo, may be denied the pleasure of meeting Dr. Otto Brandt, they may none the less be interested in the following résumé of his dissertation on: "The Education of Apprentices in the Foundry," presented by him at the joint meeting of the German Foundrymen's Association and the Association of German Iron and Steel Manufacturers, held at Koblenz, Germany, September, 1911.

The *foundry*, although using machinery to some extent, is still one of the places at which skill of hand and judgment play an important part in the attainment of first-class work. Judging the intrinsic value of the workman by the degree of mechanical skill, sound judgment, and sense of responsibility displayed in the production of his work, then the work of a first-class molder stands high in the scale of industrial value, notwithstanding the lowering of this value to some extent by modern mass production. The foundry is one of those industries which has to provide for

its own supply of skilled men since there are no other related industries which could serve in any way, or be useful as preparatory agencies for the trade of a molder. Not even the skilled molder in one class of molding is always able to use his skill successfully in another class. Hence the problem of the training apprentices in the foundry is the more important since the burden has to be assumed almost exclusively by the foundry itself. The problem is not made easier by the fact that there is a prejudice among young people to learn the trade of a molder, and notwithstanding good wages, the supply of good molders seems to be decreasing rather than increasing.

The rules under which apprentices are accepted in Germany are quite uniform. They are based upon the customary written apprenticeship contract with a trial period and an increasing scale of wages, the latter generally beginning with one cent per hour the first year, with twenty-five cents additional per week; one and one-half cents per hour the second year, with thirty cents additional per week; two cents per hour the third year, with thirty-seven cents per week additional. Then two and one-half cents per hour the fourth year, with fifty cents per week additional. At some places a little more is paid; from one dollar to one and one-quarter dollar per week the first year to two and one-half dollars per week the fourth year. This has naturally brought out the question whether more boys would not be attracted to learn the molder's trade if the pay were better. In some large shops the best boys are given piece work during the last year to give them an opportunity to earn more.

It is frequently the custom to assign an apprentice to the care of a skilled workman as a helper in order to receive practical instruction. Only such workmen are selected who are able to give proper instructions. The increase in earnings of the workman due to the help of the apprentice are his compensation for teaching the boy. If, however, the boy makes rapid progress and the foreman notices the earnings of the teacher-workman rises rapidly, due to the efficient help of the boy, then the boy's pay is gradually deducted from the earnings of the workman and if still rising then the workman is requested to give the boy some extra compensation. In order to attract boys and to prevent their gravitating towards the larger industrial centers, premiums

are often paid ranging all the way from twenty to seventy-five dollars, payable at the expiration of the apprenticeship.

Apprentices everywhere are compelled to deposit a small amount of their earnings with the works' saving fund, which is returned to him with interest at the end of his apprenticeship. The character and extent of the apprentice school at a works is naturally determined by its nature and extent. Whether it is a general apprentice school without specialization for special branches, or whether it is an industrial continuation school with special branches. Thus, where the foundry is a department of a machine shop or electrical work the foundry apprentices are likely formed into a special class with instruction pertaining to foundry work, provided there are enough boys to form such a class. If there are not enough to form special classes, then all are given general instruction in the industrial continuation school. Or groups of co-related branches, like molders, pattern-makers and machinists are instructed together.

With some concerns all apprentices are instructed together the first year and specialized in the following three years. There is no uniformity as to subject matter or time taught. It varies all the way from a school with one class and four-hour instruction per week only, to a complete three-class system with a preparatory school and twelve hours per week instruction. Again with some schools purely technical subjects, applying directly to the work on hand, are considered only, while others and the majority of them carry out the regular continuation school curriculum with such additions or deductions or specialization as necessity or convenience may demand.

It may be mentioned here that every employer has to send his employees under eighteen years of age to a continuation school for a prescribed number of hours per week, be it a shop school or a school provided by the municipality. Every employer is at liberty to maintain a school of his own on his own premises at his own expense. But if so, the school must conform to certain government requirements concerning number of hours taught per week and given subjects. The school is not allowed to fall below this standard. The employer may go above this standard to any length he desires.

The subjects taught include German language, civics, shop

practice, knowledge of materials, including specialized instruction pertaining to one particular trade, metallurgy, arithmetic, bookkeeping, natural science, physics, geometry and drawing. One or the other of these subjects, as for instance bookkeeping, may be left out and the time given to a certain subject may vary, according to the special needs of a concern.

The time arrangement is likewise a matter of convenience with each concern maintaining a shop school. Some have school from 7 to 9 A. M., or 5 to 7 P. M.. or any other hour. Some have school for an hour and a half or two hours on Sunday. Sunday school work, however, is not frequent any longer, neither with municipal industrial schools nor with shop schools.

A few details of only one typical school are here presented.

German Language.—Two hours per week. First year.

Letter Writing.—Business Practice, Bills, Receipts, Shipping Notices, Postals and Railroad Forms, etc., Compositions, Reading and Discussion of Trade Topics.

Materials.—Two hours per week.

Metals.—Their ores, where found. Processes of conversion. Blast Furnace, Cupola, Bessemer, Open-hearth Furnace, Crucible, Malleable Iron, Alloys, etc.

Woods.—Kinds, and their Properties, Diseases, Protection.

Arithmetic.—Two hours per week.

Business Arithmetic.—Cost of Materials, Buying Materials, Freight Charges.

Weight of Different Metals.—Mensuration.

Drawing.—Six hours per week.

A continuation of the same subjects during the remaining three years of apprenticeship, twelve hours each week, suitably enlarging and broadening the knowledge of the subjects presented, specializing where necessary. During the last two years business law, civics and industrial history are added.

In some instances the German language and civics are either entirely neglected or receive but scant attention. If the industries complain of the growth of Socialism then the means to prevent or modify this tendency should not be neglected. One of these means is a broad general education concerning citizenship in our industrial schools, in order to enable the industrial worker to judge for himself and get an insight into the political and social

problems of the day. The wisdom of the practice, indulged in in some quarters, to lay excessive stress upon the acquisition of purely technical subjects, may be questioned. In the pursuance of every day shop routine the average working man does not require such a surplus of technical knowledge.

In this respect we may all agree with the recent decree by the Minister of Commerce and Industry of Prussia, concerning the curriculum and equipment of the industrial continuation schools, when he says: "The compulsory industrial continuation school should aim at the vocational education of the young people between fourteen and eighteen years of age, to promote that education and to educate them up to become valuable citizens and respected men." It is gratifying to note the willingness of the management of all works to arrange for school hours during day time, and to provide the necessary school material either free or at cost.

Shop schools are necessarily limited in numbers and it is therefore gratifying to acknowledge the willingness of the municipal compulsory continuation schools to adjust themselves to the necessities of local conditions and, when desirable, arrange special trade classes. Thus, in Düsseldorf, of 214 classes in the industrial continuation schools only 74 were general. All others were special. As these schools are now constituted the foundry derives but little benefits from them unless they are to be equipped for foundry work.

Much of what Dr. Otto Brandt says in the above résumé is applicable, in one way or another, to our own educational situation, and may therefore be found interesting to the members of the American Foundrymen's Association.

REPORT OF THE COMMITTEE ON INDUSTRIAL EDUCATION, 1912.

Your Committee on Industrial Education is pleased to report a growing demand for shop apprentice schools, continuation schools, and for a system of state or nationally subsidized industrial schools, leaving to local effort the adjustment of these schools to local conditions.

This growing sentiment is not only due to the urgent necessity for skilled mechanics but it is also felt that industrial education can be made to serve the purpose of educating those who do not need the highly specialized education of the skilled mechanic.

Thus there is a tendency to put a new construction on the meaning of industrial education in having it serve as an aid to the strengthening of our industries and as a help in the readjustment to new social and economic conditions.

This conviction has been forced upon the advocates of industrial education by the results of recent investigations into the educational needs of all classes of industrial workers, skilled, semi-skilled and unskilled, male and female, as being in the interest of the peace and welfare of society as much as in the interest of any particular industry.

It is felt that it would lead to social suicide to pay attention only to the higher skilled trades in any extensive scheme for industrial education. To ignore the social economic needs of the more than twenty millions of factory workers, and other millions engaged in various semi-skilled occupations who do not need the technical training of the highly skilled mechanic. The latter is nevertheless in a social, economic and industrial position to contribute his share to the success of the industrial and social fabric.

Unless we succeed in turning the latent talents and ambitions of these millions of auxiliary industrial workers into socially and industrially useful channels they will hang like a dead weight upon the wheel of progress, to the detriment of our industries and society at large.

Keeping this phase of the industrial educational problem in mind we can readily see how all the efforts of the social forces now at work, converge toward the application of the fundamentals underlying the various possible forms of industrial education.

The manufacturer and corporation officer whose need lies in the highly specialized shop apprentice school and school shop; the educator who is anxious to secure an unbroken line of manual training from the kindergarten up; the advocate of continuation schools for those who leave school at fourteen without prospect of industrial guidance; the leaders in the movement for organized and supervised social industrial play and recreation; the social worker who devotes his or her time to the prevention of the mental and physical degeneration of the millions who are in danger of being submerged in the struggle for existence and become a menace to society; these all look to industrial education in some form as a helpful instrumentality in their laudable efforts.

This then is the present trend in the conception of the largest usefulness of industrial education. The success of each and all is largely dependent upon the success of either in the long run.

What are these Fundamentals?

First.—It is fundamentally necessary to have the mental and physical powers of the industrial worker so developed as to serve vocational as well as civic purposes.

Second.—The industrial school should not only train in manual dexterity, but also diffuse a primary knowledge of the technics and economics, as well as of the business side of the occupation of the worker in factory, shop, store and office.

Third.—The development of will power by judiciously directed work, play and recreation by teams, groups or whole classes.

Fourth.—Cultivation of the understanding that the industrial, social and economic interests of the industrial worker depend upon the success and welfare of the interests of his fellow citizens and co-workers, upon the businesslike management of the affairs of the municipality, the state and nation, and freedom from political corruption.

Practical Usefulness of These Fundamentals.

First.—The degree of intellectual development of the members of a community may vary, and does vary, without harm to that

community, provided a person is mentally and physically equipped for the performance of his or her particular vocational and civic duties and responsibilities. It is waste of time, money and energy to put a two thousand dollar man into a thousand dollar job. But it is essential to the welfare of all that every one enjoy physical health. The greater the number of those physically incapacitated the greater the burden upon those remaining able to do the necessary work. Hence the fundamental value of industrial education to direct the attention of the industrial worker to the necessity of obeying the laws of health and sanitation, as a means to the full enjoyment of the fruit of his labor.

Second.—This fundamental permits diversification of instruction in various directions and degrees of industrial life. It offers the exploitation of the field of knowledge in mechanics, technics, science, economics, applied moderately or intensively in various combinations in conformity with the requirements of the case.

Third.—The motive power of all human activity is the will. Hence the desirability of including ways and means of developing will power in any scheme of education. However, no amount of admonishing, reading of good books or preaching will develop will power. Only by setting the mental desire to do a thing into motion by actual doing, is the will exercised for good or evil. These motives are furnished in ever differing variety in industrial education so adapted to the varying requirements of the learner as to best fit him or her for the particular duties of vocational life and civic duty.

Fourth.—The success of modern industrial and commercial undertakings demands co-operation of all connected with them in any way. This likewise holds good with reference to the proper management of public institutions. This co-operation is the result of the comprehension of the fundamental principle in social life that where any number of people dwell together for mutual protection and benefit each one has to sacrifice part of his personal desires for the good of the whole community. To develop and cultivate this understanding is part of the function of that broader industrial training which teaches not only the skillful use of one's mental and physical powers, but also how to economically conserve these powers for the best interests of the individual as well as of the community.

In this latest conception that under our form of government industrial education lends itself to the service of all social forces in variegated forms of application we find the justification to demand liberal support from municipalities, state and nation for the establishment of a system of continuation, industrial and trade schools as part of our educational system, but carried on separately from the traditional common and high schools. Your chairman attended the annual meeting of the National Education Association at San Francisco, last July, and was very agreeably impressed with the progressive spirit and ideas manifested by the educators on the Pacific Coast, all the way from Seattle to Los Angeles, concerning the need and scope of industrial education. Your chairman also attended the annual meeting of the National Society for the Promotion of Industrial Education, held at Cincinnati last November. The meeting was well attended and some instructive papers were presented. The result of the examination into Cincinnati's compulsory and voluntary continuation schools by your chairman is appended.

It is gratifying to report a steady demand for the reports of your committee, the whole supply having been exhausted. This demand covers all parts of the country, from Winnipeg in the north to Atlanta in the south and from Los Angeles to Boston. In several cases the advice and opinion of your committee was sought concerning the prospective establishment of industrial schools.

Your chairman was again honored with an invitation to take part in the discussions of the Manual Training Department at the annual convention of the National Education Association at Chicago, July 6–12, 1912. The question assigned for discussion was: "Can, or ought, the seventh and eighth grades be made preparatory for the continuation school or the industrial course in the high school?" The putting of this question upon the program of the National Education Association for discussion is very gratifying, and creditable to the school people since it manifests a recognition of the intimate relation and interdependence of the effectiveness and value to our industrial communities from the co-operation of the common school with the industrial and trade school. Your committee has urged such a co-operation for some time.

Your committee recommends for the foundrymen to unite with other industries in their respective locality to urge upon the school authorities the establishment of continuation schools or part-time schools where conditions do not favor the establishment of specific foundry schools.

Your committee also asks the members of the American Foundrymen's Association to write to their representatives in Congress, urging the passage of the so-called Page Bill, which bill favors the establishment of secondary industrial schools through Federal subsidy.

PAUL KREUZPOINTNER,
Chairman

APPENDIX I.

CINCINNATI CONTINUATION SCHOOLS. COMPULSORY AND VOLUNTARY.

At the time of the visit of your chairman the compulsory continuation schools of Cincinnati were chiefly elementary schools designed to continue the elementary studies of the grades in the common schools which the pupils had left to go to work at fourteen years of age. These schools are provided for those who had not advanced further than the sixth grade.

In other words, the school aims to advance these sixth grade pupils of an age where they can ask for a certificate to go to work to the elementary school attainments of the eighth grade. It is the intention, however, to add industrial subjects after the schools had settled down to an effective working basis, being only in the second year of their existence when visited. The employers have to send these children to school one hour a day until they are sixteen years of age. There are twelve of these schools and the superintendent and teachers felt assured that the plan worked smoothly and satisfactorily.

The voluntary continuation schools of Cincinnati were established through the efforts of the metal trades of Cincinnati, and at the time of the visit, November, 1911, were attended by 240 apprentices from twenty-four trades and forty-six shops. A

continuation school for printers had just been established. The employers do not compel their boys to attend the school. But if any elect to attend they become subject to the rules of the school and are paid their wages while absent from the shop. If late or absent without cause they lose their pay, or in case of misbehavior in school they lose part of their pay as punishment. The closest co-operation prevails between the school and shop authorities in regard to discipline and the work on hand. Each boy receives five hours of schooling per week. Saturdays the instructors visit the shops to note the progress of the boys.

The method of teaching is eminently practical and radically different from the usual school methods. No machinery is used in the school, the boy being supposed to acquire the necessary mechanical skill in the shop. It is the object of the school to supplement the mechanical work of the boy in the shop with such knowledge which he does not get in the shop, but is nevertheless essential for a good mechanic. Drawing is confined chiefly to making sketches of parts of machines. Regular school text books are not used, though they are at hand if wanted. A variety of trade catalogues are used for the double purpose of improving the English of the pupils as well as to use the cuts and description of machinery as practical lessons in mechanics. Hundreds of stereopticon slides are on hand, illustrating machines or mechanical devices and throwing the one or other on the screen; while the boy, having the catalogue before him, gives the name and explains the function of the part. Then sketches are made of single parts and the underlying principle of the geometrical construction and calculation are taught. Often, boys who find themselves deficient in mathematics strike a bee line for the case containing the school text book to make up their deficiency.

In this way the continuation schools, both the compulsory and voluntary, have been found to have a stimulating influence upon the grades below. A "Machine Shop Primer," devised at the suggestion and with the aid of the efficient director of the voluntary continuation school, Mr. J. Howard Renshaw, and published by the *American Machinist*, is used and with the aid of this primer the boys learn the names and functions of the mechanical devices and at the same time get their vocabulary.

Photographs are taken of boys running a machine in the shop,

slides are made and thrown upon the screen in the school to explain the right or wrong position of the boy while doing the work. The boys are asked when they are paid, why they are not paid the same day their time is handed in and to make out a pay roll for a given number of men. Besides the lesson in arithmetic it gives them an insight into business methods.

The school aims to develop two fundamental principles: attitude and intelligence. Intelligence to be developed by concrete examples and their application to every-day work in the shop, in the home and in public life. To this end the purely mechanical and mathematical part of the instruction is enlivened by related circumstances in the trade and history of Cincinnati, its past, and its future prospects, the relation of economic necessities to the industries of the city and to the state. The raw materials and their products used in the trades of the boys are explained. Economics of time and materials. History as related to our industries and the influences of noted men upon the development of our industries. The duties of the citizen in the community.

Two factors enter into the proper attitude towards the employer. Skill and knowledge of the man how to execute the product. Knowledge on the part of the employer how to use that skill to produce a salable product. This knowledge of the employer entitles him to the confidence and respect of the employee because lack of this knowledge is disastrous to both the employer and employee. This attitude towards the employer is intimately related to the attitude towards one's work. Attitude towards one's work is developed by the industrial intelligence acquired in the school.

Attitude towards one's self is fostered by insisting on personal cleanliness, tidiness, promptness, accuracy, pleasure in work and willingness to develop talents. Using one's recreation to the best physical and mental advantage. Attitude towards the community is developed by an understanding that communities are built up by the exertion, economy, physical strength, energy, self-sacrifice and knowledge of the individual. That every member of a community ought to strive to see that every dollar which goes out of the community be stamped with the seal of industry,

skill and industrial intelligence. That is to say that it has been earned in fostering progress and the reputation of the community.

Such, in brief, is the scope of the voluntary continuation schools of Cincinnati.

Paul Kreuzpointner,
Chairman.

APPENDIX II.

Synopsis of Address Delivered at Meeting of the Manual Training Department, National Education Association, Chicago, July, 1912, on "The Relation of the Elementary School to Subsequent Industrial Training," by Paul Kreuzpointner, Altoona, Pa.

There seems to be a consensus of opinion among interested parties that the success of the continuation school, of the industrial course in the high school, of the trade school and of the shop apprentice school is retarded because of lack of preparation in the elementary schools below.

It is the function of the industrial school of whatever kind to aim at the immediate economic usefulness and practical application of the knowledge acquired. In this respect industrial education differs radically from general elementary and high school education. But notwithstanding this difference it must be acknowledged that industrial education of whatever form or name rests upon the foundations laid by the elementary and high school and that these various forms of education touch each other in many ways and their division lines frequently run into each other for long distances.

Moreover, the teaching force is more or less interchangeable.

Looking at the question from this standpoint it is obvious that industrial education in any specialized form would be the gainer if the seventh or eighth grade would be made preparatory to all forms of specialized industrial education.

We industrial men, to whom falls the task of judging of the quality of the output of present-day industrial education, are keenly aware of the shortcomings of the product the schools deliver to us, and those of us who have studied the educational

situation believe these shortcomings are largely due to the lack of preparation in the grades. The industrial school is retarded in its progress because of the necessity to do elementary work and thus is unable to advance the pupils in conformity with their ages and mental development.

In other words, the school has to stop just at the period when the student is in the best receptive condition mentally and physically, and would derive the greatest benefit from the instructions in an advanced grade of knowledge.

Such a preparation in the seventh or eighth grade for the industrial course in the high school, the continuation school, the shop apprentice school and the trade school, would also be highly useful from the social and industrial standpoint. It would be instrumental in retaining large numbers of boys in school who now either drop out or else lose interest in the abstract subjects of the common branches.

But these beneficial results will not be attained unless the number of hours teaching natural sciences in the elementary school are increased and the teachers become accustomed to teach these subjects without the use of text books.

APPENDIX III.

Summary of Address on "The Relation of the Elementary School to Subsequent Industrial Education," by Prof. William T. Bawden, Dean, University of Illinois. Read at the Annual Convention of the National Education Association, Chicago, Ill., July 6–12, 1912.

1. The elementary school should sustain the same relation to subsequent industrial education that it does to subsequent education of other kinds; it should afford training leading in all directions that are worthy, with all possible impartiality.

2. In order that the elementary school may fulfill its function of providing the education needed for all, it must definitely abandon the idea of one curriculum for all.

3. The elementary school should encourage in its pupils the development of vocational purposes in their efforts toward education. The pupils must be convinced that the school is able to

help them discover and define these purposes, and that as soon as these purposes are defined in their own minds the school is prepared to offer definite assistance in their realization.

4. The school should make more of the appeal to altruistic motives, emphasizing the ideal of education for social service.

APPENDIX IV.

Synopsis of Discussion on Prof. William T. Bawden's Address on "The Relation of the Elementary School to Subsequent Industrial Education," by P. Kreuzpointner, Altoona, Pa.

Those who are under daily obligation to adjust to their work the material received from our schools, appreciate the willingness of the educators to have the elementary school take part in the work of preparing those who are destined to enter industrial life direct from the elementary school.

If we retain our present conception of the function of industrial education; that it is to be only an instrument to increase output and to furnish the means to a comfortable material existence; then by the everlasting appeal to the selfish instincts of the employer and the employee a state of mind will eventually be produced which will react injuriously alike upon the industries and upon society.

Those who have the opportunity to analyze the mental attitude of the industrial worker cannot but help to come to the conclusion that much of the friction and misunderstanding in industrial life would be avoided if our schools were less exclusively literary or technic-mechanical, being tempered more with such altruistic elements that would promote the conception of social service being a mainstay of social stability and civic usefulness.

The readjustment in the direction indicated would also react favorably upon the teachers by improving their social standing and influence, which are now often withheld because of the absence of that intimate relation elementary education might bear to the life of the industrial worker.

Are we willing to admit that educational progress concerns s elf solely with the education which lies beyond the elementary hool?

Taking Dr. Stanley Hall's "Adolescence" as a criterion we could safely introduce into the eighth grade, with suitable correlation of academic subjects, the teaching of elementary knowledge of food, textiles, wood, minerals, metals and physics.

I am not pleading here for specific industrial education but for that broad general and cultural civic education which should give the industrial worker an insight into the relation of his work to his civic responsibility. The insight of this can only be acquired satisfactorily by active exercise, aided by a knowledge of the nature, use and means of how to preserve one's health and strength, and those material substances wherewith we have to sustain our material and spiritual life, our social and political institutions and our civilization.

APPENDIX V.

Resolutions on Industrial Education. Adopted by the National Association of Manufacturers at its Seventeenth Annual Convention, New York City, May 21, 1912.

WHEREAS, one-half of the children in the common schools of the United States leave school by the end of the sixth grade, with no substantial educational acquirements beyond reading, writing and arithmetic in their simpler forms, the essential of education and citizenship coming, if at all, after the sixth grade, and

WHEREAS, this half of the children soon forget much of what they learned in their brief school experience, and

WHEREAS, truancy and absence are so prevalent that less than three-fourths of the children are in school as much as three-fourths of the time, the enrolment being 17,000,000 and the average attendance being under 12,000,000, 1,600,000 being permanently absent from, and unacquainted with school life, and,

WHEREAS, illiteracy in the United States is fifty times that of several continental countries and is four times greater among the children of native whites than among the native-born children of immigrants, and

WHEREAS, in many schools and many cities educators are finding great cultural and educational value in the development

of the motor activities, the practical and creative desires of the youth, in highly developed practical and extended courses in manual and pre-vocational training, and such courses are developing in an unexpected degree, an appreciation of the dignity of labor of all kinds, and such moral qualities as diligence, concentration, perseverance and respect, and causing many to successfully continue in school who otherwise would leave discouraged, early in the course, and

WHEREAS, a majority of the children who leave school prematurely, do so from no economic need, and in fact are idle about half the time between their fourteenth and sixteenth years, being the first two years out of school, and average for the first two years little over $2.00 per week in earnings, leaving school principally because their interest in practical and creative effort is not provided for, and

WHEREAS, the loss to the schools of 50 per cent of the children in the middle of the elementary school courses is an incalculable waste of the human resources of the nation, these human resources being estimated by Professor Fisher as of the economic value of $250,000,000,000, and five times the value of all our other natural resources combined.

Therefore, for these and other reasons, the National Association of Manufacturers by Resolution pledges its earnest support of the following principles of educational betterment as essential to society and to the spiritual, social and physical welfare of the youth.

1. Continuation schools for that half of the children who leave school at fourteen years of age, and mostly in the fifth and sixth grades, these continuation schools to be liberally cultural and at the same time to be extremely practical and related as directly as possible to the occupations in which the several students are engaged.

2. The development of a modern apprenticeship system wherein by contract the respective and equal rights of employer and employee are fully recognized, and the entire trade is taught, together with such other subjects as are essential to good citizenship.

3. The development of secondary continuation or trade schools, by which the more efficient of the great army of boys

and girls who will enter the continuation schools may progress from these lower continuation schools, as in some other countries, to the foremost places in industry and commerce.

4. Compulsory education through adolescence being until the seventeenth or eighteenth year, attendance being in the all-day school until the fourteenth year, and thereafter in either the all-day schools or in the continuation schools for not less than one-half day per week, without loss of wages for hours in school.

5. The strengthening of all truancy laws and the development of public sentiment in support thereof.

6. The training of teachers in thorough-going methods of industrial practice, including as part of such training extended experience in actual shop work.

7. The establishment of independent state and local Boards of Industrial Education consisting of one-third each, professional educators, employers and employees, thereby insuring, as in the more successful European countries, the proper correlation of the schools and the industries.

8. The development of the vocational and creative desires of the concrete—or hand-minded children now in the grades, discouraged, anxious to quit, and often called backward, only because the education now tendered them is abstract and misfit.

9. The establishment of shop schools and part-time schools wherever practicable.

10. The establishment of departments or centers of vocational guidance so that the great majority of the children who now enter industry at fourteen with no direction, 85 per cent falling into the "blind alley" occupations, may, with the reversal of these figures, as in some other countries, enter under advice, intelligently and properly into the progressive and improving occupations.

Resolved, by the National Association of Manufacturers, that it is the imperative need of the industrial workers and employers of the country that through-going systems of industrial education be everywhere established so that our factories may be more constantly and better employed; that standards of skill and of output may increasingly be improved, and that foreign and domestic markets may be better held and extended.

AIR REQUIRED FOR COMBUSTION IN THE CUPOLA, AND A SIMPLE BLAST VELOCITY GAUGE.

By P. Munnoch.

In ordinary cupola practice and also when making special melting tests, one of the unknown factors is the quantity of air used, this being usually assumed from the speed of the blower or fan.

In the case of a blower, the amount of air delivered depends to a great extent on the speed of the blower, owing to the effect of wear upon the impellers, and to varying conditions the efficiency of the blower may vary to a considerable extent, and may actually figure only sixty to eighty per cent of the theoretical displacement of the impellers. Where relief valves are set to blow off at a certain pressure, the amount of air delivered when this point is reached is an unknown quantity.

In the case of a fan, while the amount of air delivered depends upon the speed and the pressure against which it operates, there is a maximum pressure for each speed above which any increase in back pressure decreases the quantity of air delivered. Therefore it is possible for conditions to exist under which there is a greatly decreased quantity of air delivered, and no indication is given except a slight increase on the pressure gauge.

The cupola is to some extent like a blast furnace, in that it is a coke-consuming furnace, and the rate at which it works depends upon the rate at which the coke is burnt, which in turn depends upon the rate at which the air is supplied. There is a difference, however, in the two cases; in the blast furnace all the fuel reaching the furnace hearth is burnt to carbon monoxide, or if any carbon dioxide is formed it is converted into carbon monoxide by the excess of fuel before reaching the upper part of the furnace.

In the cupola combustion of carbon is more complete, and the carbon is to a great extent burnt to carbon dioxide. Owing

to the varying conditions which exist in the cupola, the completeness of the combustion is ever varying, therefore the amount of air supply is not as absolute a guide to the rate of working as in the case of the blast furnace.

The statement is sometimes made in papers relating to cupola practice, that a definite quantity of air is required for a definite amount of coke in the cupola, but as to how this can be regulated no information is forthcoming. Of course it is practically impossible to put in a certain amount of coke and then blow in the proper quantity of air required for combustion. Alteration may be made in the pressure or in the quantity of air delivered, but the action inside the furnace is more or less self-adjusting, if the quantity of air is increased the rate of melting increases, on the other hand if the amount of air is decreased the rate of melting accommodates itself to the changed conditions.

Considering the cupola as a gas generator, or gas producer, one would expect to find that the greater the height of the materials in the furnace, the more carbon monoxide and the less carbon dioxide will be found in the issuing gases, due to the action of carbon dioxide upon the heated coke. Therefore above a certain minimum height the greater the distance from the tuyeres to the top of the material in the cupola the less the efficiency obtained from the fuel used. This would to some extent be offset by the greater amount of heat taken up by the descending materials, large heavy materials which take up heat slowly being most benefited by the longer time taken to reach the tuyeres.

Cupola gases vary considerably and combustion is never complete, therefore the amount of air used is below that theoretically required to burn all carbon to carbon dioxide. Taking as an average composition, a gas containing about 8.2 per cent of carbon dioxide, 19 per cent of carbon monoxide and 72.8 per cent of nitrogen, the amount of air used would be about 84 per cent of the theoretical quantity.

Amount of Air Required.—Carbon burning to carbon dioxide requires 32/12ths its weight of oxygen. Carbon burning to carbon monoxide requires 16/12ths its weight of oxygen. Dry air contains 23.1 parts of oxygen to 76.9 parts of nitrogen by weight. Air weighs .0808 pounds per cu. ft., or 12.37 cu. ft. per pound.

One pound of carbon requires 11.544 pounds of air for combustion. One pound of air requires 142.8 cu. ft. of air for complete combustion.

Amount of Air to Melt Iron in Cupola.—A cupola melting 2,000 pounds of iron per hour at a ratio of 200 pounds of coke to 2,000 pounds of iron, with coke containing 90 per cent of carbon, requires 25,704 cu. ft. of air, or 7.14 cu. ft. of air per second for complete combustion, air at normal pressure and 32° F.

As the temperature increases air expands and therefore a greater volume is required. At a temperature of 77° F. the increase in volume is about 1/11th. Pressure decreases the bulk of air, a pressure of 12 ounces decreasing the volume by about 1/20th.

Effect of Moisture.—Moisture is always present in the atmosphere, the amount varying considerably from time to time, there being two or three times as much in the summer as compared with the winter months. In addition to the natural moisture, the air may contain water vapor drawn from the foundry or engine house. Taking about 5.5 grains of moisture per cubic foot of air as an average figure, this would contain oxygen equal to about 1/26th part of that present in the air used. Under different circumstances, this might either consume an extra amount of coke or take the place of some of the air used. As this moisture will be all decomposed in the hearth of the cupola, this lowers the temperature below that otherwise attainable. It is possible when air temperature is high to have two or three times this amount of moisture present in the air used; therefore the effect may be great upon the amount of air used. Owing to the great amount of heat abstracted from the cupola hearth, it will have a great effect upon the amount of coke required for melting.

A Simple Blast Velocity Gauge.

The most simple form of apparatus which can be used to measure the velocity of air passing through a blast tube is the Pitot tube and gauge. The form suggested is probably the most simple and easily made, and the cost is very small.

To obtain results which are scientifically accurate a thousand and one precautions are necessary. The object of this article is not to describe an instrument for scientific purposes, but to sug-

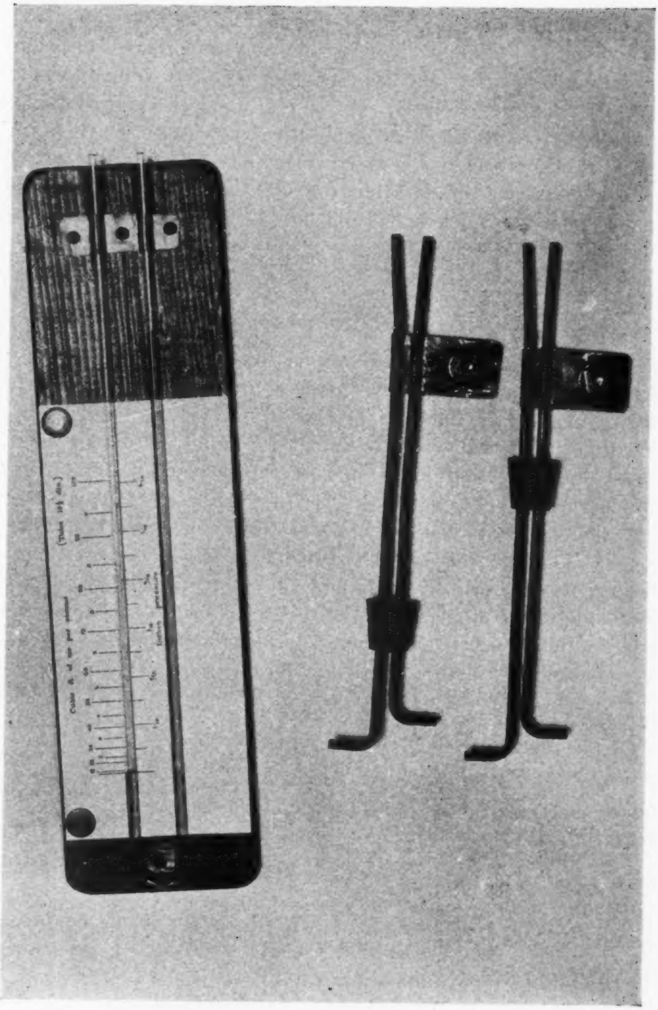
gest a simple instrument by which the ordinary foundryman can obtain some idea of the amount of air being used in the cupola and thus obtain figures which will have some comparative value when compared with cupola performances from time to time. As an index to the rate of melting, it should at least be of more value than the ordinary pressure gauge with which practically all cupolas are fitted.

The Pitot tube is made from two pieces of brass or copper tubing one-eighth of an inch in diameter and about nine or ten inches long, about one inch length of each being bent at right angles. The tubes are put through two holes in a No. 4 rubber cork, ¾ of an inch in diameter at the small end. Two flat strips of copper are then soldered to the copper tubes, so that when the two strips are screwed flat together, the two bent ends point in exactly opposite directions, and so that one end projects about half an inch beyond the other. The bent ends of the copper tubes should be tapered from the inside to a thin outer edge.

By removing the small bolt by which the tubes are held together they can easily be inserted in the small hole made in the blast main to take the rubber cork.

The gauge is made from a piece of glass tube about 1/8th or 3/16th of an inch in diameter, bent to a U shape, which should measure about 15 inches long. This is fixed to a back board by means of thin strips of metal. The scale, to be described later, is marked out on a piece of cardboard and slipped in behind the glass tube, being fixed in place by drawing pins or other means.

The pressure to be measured is very small, usually below one half inch water pressure; therefore some means of magnifying the small movement of the column of liquid is necessary. The most simple way of doing this is to incline the gauge tube. If water is used in the gauge tube, an inclination of one in ten from the horizontal increases the travel of the water column by five times that obtained with the gauge in a vertical position. Water is not satisfactory owing to the sides of the tube becoming dry and resisting the movement of the liquid and also preventing it from returning to zero after being in use. Common kerosene is more suitable, but as the specific gravity is less than that of water, a greater inclination to the horizontal is necessary to give



the same five-to-one travel. With kerosene of .795 specific gravity an inclination of one in 7.95 inches is necessary.

Instead of the inclined tube, some form of differential gauge may be used for increasing the magnitude of the readings; where a portable gauge is required this type of gauge is more suitable. There are two forms listed in chemical catalogues, one in the form of a U tube with enlarged ends, containing two liquids, one of which is colored and the other colorless. The other form, the Koenig differential gauge, having one of the tubes placed concentrically inside the other, also containing a colored and a colorless liquid.

Calculation of Velocity.

There are several factors which must be considered when accurate results are necessary; these are factors affecting the density of the air, such as height of barometer, temperature, pressure, and humidity of the air at the point of measurement. Under ordinary conditions some of these to a greater or less extent neutralize the effect of one another; for the purpose in view, we may leave them out of consideration and thus be enabled to construct a scale from which we may read off either velocity or quantity in cubic feet per unit of time, one second being a suitable unit. Otherwise we would be compelled to make a very elaborate mathematical calculation for each observation.

The following is the usual formula for calculating velocity.

for water: $$\text{Velocity} = \sqrt{2g\ h}$$

g gravity: h height of water column.

for air: $$\text{Velocity} = \sqrt{2\ g\ \frac{h}{d}\ w}$$

Velocity in feet per second.

g gravity 32.16 ft. per second.

h height of water column in feet.

d density of air or gas to be measured.

w density of water compared with an equal bulk of air at standard temperature and pressure.

Reduced to its simplest form, the formula becomes:

[redacted] $$\text{Velocity in feet per second} = 64.36\sqrt{\frac{h}{d}}$$

h height of water column in inches.

d density of air or gas compared with air at standard temperature and pressure.

$$\text{or Velocity in feet per second} = 12.771\sqrt{\frac{h}{d}}$$

h height of water column in millimeters.
d density of air or gas compared with air at standard temperature and pressure.

As the temperatures and pressures to a great extent neutralize each other, the readings, if calculated as normal pressure and temperature (32° F.), will approximate actual volumes and weights, which may be compared directly with the theoretical amount of air required for combustion.

To make scale from the above formula, we reverse it and obtain

$$\left(\frac{\text{(velocity in feet per second)}}{64.36}\right)^2 = \text{inches on scale.}$$

As it is more convenient to read off the actual amount passing along the blast pipe in cubic feet per second, the area of the blast pipe is inserted in the formula, which then reads:

$$\left(\frac{\text{velocity in feet per second}}{\text{area of blast pipe in sq. ft.} \times 64.36}\right)^2 = \text{inches on scale.}$$

The following table is calculated as above and shows velocity in feet per second. With blast pipe of one square foot area the readings would indicate cubic feet per second.

Water Gauge in inches.	Water Gauge in millimeters.	Velocity in feet per second.
.006	.15	5
.024	.61	10
.054	1.37	15
.096	2.45	20
.150	3.82	25
.217	5.41	30
.295	7.50	35
.386	9.74	40
.498	12.41	45
.603	15.32	50
.740	18.54	55
.869	22.07	60

The inclination of the gauge tube multiplies the movement of the liquid five times; the Pitot tube described, having one limb operating by pressure and the other by suction, multiplies the movement by two, the net result is that the movement of the liquid in the gauge is magnified ten times. Tenths of an inch on the scale will therefore represent hundredths of an inch, and scale to read in cubic feet per second is calculated and marked off to correspond.

The Pitot tube is inserted in the blast pipe so that the open ends of the tube are at right angles to the flow of air.

The velocity of the air in the blast pipe is much greater in the center than near the circumference; to obtain an average reading the Pitot tube is inserted from one-sixth to one-fifth of the diameter into the blast pipe. It should also be inserted in a straight length of pipe, as far as possible away from bends.

The gauge tube should be fixed on a wall or other support as near as possible to the blast pipe, and inclined at the correct angle. It should be connected with both limbs of the Pitot tube by means of rubber tubing or with thin copper tubing, in which case short rubber connections are used. As one side is pressure and the other suction, the end of the Pitot tube which points towards the blower is connected with the lower limb of the gauge, the opposite tube being connected with the higher limb. Both connections must be made before the blast is put on, or the liquid will be blown from the gauge tube by the blast pressure.

The illustration shows the gauge and also two pair of tubes.

THE GREAT ECONOMIES PRODUCED BY CONTINUOUS FOUNDRY INSTALLATIONS.

By George K. Hooper, New York City.

Following a suggestion from your Secretary—that I enlarge a booklet recently gotten out by me, in which I discuss "Continuous Foundry Operations"—and since you all doubtless know what a continuous foundry system is, I shall discuss the "Results" obtained, knowing that you will be interested more in comparative figures than in the mere arguments in favor of such a system.

The advantageous results which have been successfully attained by the use of the continuous method are:

Principal:

1. Reduction in wages.
2. Reduction in number of operatives necessary for a given production, or increase in efficiency of labor.
3. Reduction in floor space.

Collateral Advantages:

4. Reduction in investment in small equipment.
5. Reduction in foundry loss.

The first item is Reduction in Wages. It is an economic fact that these can be somewhat reduced, due to the lessening of responsibility through simplification and reduction in number of operations per individual, of mold making and such other functions as make up the work of manufacturing any particular casting. If no labor-saving foundry machinery is used and skilled or well organized labor is employed, this reduction in wage may be considerable, amounting in one instance in the writer's work to about 40 per cent. In that particular case, this saving alone would have justified the installation, since it applied to about one hundred men and the whole installation cost about $40,000 exclusive of buildings.

This average difference in wage applied to all of the labor employed in operating the continuous plant. In other words, if the continuous plant had been isolated, its total payroll would have been about 40 per cent less than the payroll in the original plant, the continuous plant producing a slightly larger output at once, which increased considerably later on.

Where molding machines are in use, operated by comparatively unskilled labor, this wage saving may or may not exist. As an economic proposition it is possible, but it is not always practicable to take advantage of it. This does not reasonably mean that the continuous method is inapplicable to such cases, as it is possible by means of a properly planned continuous system to obtain a greater output per man than without it.

The greater output per man or greater efficiency may be enlarged upon as follows: Machinery improves the efficiency of labor in the foundry exactly as in any other art. In the foundry, this isdeveloped in two ways: First, through having everything most conveniently arranged for the application of what manual effort the laborer is called upon to furnish, and secondly by the substitution of operations performed or guided by machinery for muscular ones. The average increase of efficiency of foundry labor, due to the introduction of continuous methods, is about one-third. As a result of the study of foundries on work which can advantageously be done by continuous methods, it has been found that the efficiency of well conducted hand operated foundries, though varying considerably, average about 50 per cent with a possible maximum of 55 per cent. This means that the men do about half of the useful work which it is theoretically possible for them to do.

In the conveyor foundry, the average efficiency is about 65 per cent with a possible maximum of about 70 per cent. There is thus possible an average increase in labor efficiency of about one-third, with a possible maximum increase of about one-half. There are few, if any, continuous systems operating at higher than 70 per cent, and this represents about the best plant efficiency in my opinion, of which the foundry is capable to-day. Perhaps the permanent mold when in successful general operation will increase this somewhat. The above figures, are, however, large enough to be interesting to the foundryman. To be able to

get out his present production by the use of about three-fourths of his men or to increase his production about one-third with his present force, is, with its collateral advantages, an attractive proposition.

The above limits of efficiency will reveal the reason why some foundries operating without the continuous system show practically as good results as some operating continuously. It is apparently possible in the same line of work to bring a well organized and administered hand operated foundry up to an efficiency about equal to that of a poorly designed and administered continuous foundry, making the operating costs of the two methods about the same. This should not militate against the continuous method, however, since, as a general proposition, it is practically always possible to increase, by means of well planned machinery, the efficiency of hand labor, however great the efficiency of the latter may be; consequently a properly planned and operated continuous system cannot fail to produce lower costs than any hand method, provided the product be adapted to continuous handling.

(3) *Reduction in Floor Space.*—The foundry floor space necessary for a given output is practically cut in half. From my experience, I regard this as a safe statement. In one installation, 7,500 molds are produced, poured and shaken out on 7,000 sq. ft. of floor space. This comprises all floor space that is used in molding, melting, pouring, shaking out and separating. The molds are the average snap molds.

In another, 7,200 molds averaging about 3.9 sq. ft. per mold are produced, poured and shaken out in a space of about 9,500 sq. ft. This space includes melting equipment, and all conveyors as before.

In another plant, 110 tons of iron have been poured per ten-hour day for 38 molding stations on a floor space of 12,800 sq. ft. I cannot give offhand the average size of mold, as a great variety of work is done in this foundry and the molds vary from snap sizes up to molds of about three feet square.

With foundry floor space worth an average of $2.00 per sq. ft., a direct comparison can be made by yourselves without burdening this paper with it.

Recently there has been occasion to make a direct comparison

in the design of a foundry with a present capacity of 18 tons and ultimate capacity of 50 tons. With the production question, the latter output warranted the introduction of continuous methods, and the same floor space served for both tonnages; that is, 18 tons by hand and 50 tons by continuous operation, so that here is a case where the continuous method required but about 40 per cent of the floor space of hand methods.

You can realize the resulting saving in buildings, land and handling could you turn out your product on half your present floor space or double your production in your present foundry.

The preliminary plan has been recently completed for remodeling a foundry in which by continuous operation there will be about 12,000 molds per day made, poured and shaken out in about 12,000 sq. ft. This installation is planned to handle a very varied line of work, both cored and solid, from molds made on small hand squeezers up to molds made on molding machines, and as heavy as a man can conveniently handle.

(4) Another point right here will suggest itself, and that is investment in individual equipment. This will diminish about as the number of operatives diminishes, or as their efficiency increases.

(5) Next is Reduction of Foundry Loss. This I believe to be an invariable accompaniment of continuous methods and the reason is not far to seek. The oftener the average workman performs an operation, the more skillful he becomes; consequently, the smaller will be his percentage of failures. When he is confined to doing a few simple things assisted by machinery, his skill is noticeably greater than when he does a greater number of things unassisted by any mechanical device. Therefore I find that the foundry loss under well planned continuous operation is but about one-half to two-thirds what it is under hand operation. This disposes at once of the oft-repeated contention that the mold maker must pour his own molds in order to secure best results. As a result of experience, I can say that better average results are obtained by continuous operation in which the mold maker does not pour his own molds, than when the same molds are made and poured by the same individual. It is obvious that a man who does nothing but pour molds, which are brought before him in a convenient position, will acquire greater skill in pouring than one

who does many other things as well. It has in fact been demonstrated in one continuous system that the pouring can be automatically done by machinery with satisfactory results so far as the casting is concerned.

It is but another example of the advantage of specialization with which all are familiar. In the first continuous plant with which I was connected, any able-bodied foreigner was taken for the pouring gang. These men each poured about three hundred hand ladles per ten-hour day in molds of varying pattern, and weight and the foundry loss was but two-thirds of the loss on the same patterns when run on the floor. This division of responsibility introduces no complications, and does not interfere with the establishment of piece-work rates.

With the sub-division and simplification of operations and the present day knowledge of pattern making, gating, shrinkage, etc., there is no trouble in defining the responsibility of any foundry operative on work which can be made continuously, so that piece-work rates may be applied to any desired operation and the pouring can be separated from the mold making with no lessening of responsibility and no increase in loss.

The reduced percentage of loss above referred to is also evidence that no damage occurs to molds, cores or castings through the placing the molds upon or transporting them by means of conveyor. In my experience I have yet to see a properly designed system in which any damage has resulted to the molds from this cause. In order to determine this point for myself, I have in the past subjected molds to violent treatment for the purpose of determining their capacity for enduring handling of this nature, and have settled to my satisfaction that no apprehension need be felt on this score with the average sand mold.

The mechanical handling and preparation of molding sand brings about an improved condition as regards foundry loss, since the sand is brought to a much more uniform temper than is possible in any other way. Blows due to spots of wet sand on the face of the mold are eliminated when the sand is tempered mechanically.

Summarizing the results to be attained as shown by the foregoing data compiled from experience, the savings to be made average about one-third to one-half on labor, one-half on floor

space, one-third on spoiled work and about one-third in individual equipment.

The investment in apparatus necessary to accomplish these results varies with conditions. The first installation handled by the writer cost approximately $40,000. A report has just been made upon a lot of foundry work in which the necessary apparatus is estimated to cost approximately $25,000 installed, and another in which the equipment is estimated to cost approximately $260,000, and still another in which the sand handling apparatus only is estimated to cost approximately $22,500. Another complete system which under rather difficult installation conditions cost approximately $30,000 for apparatus.

As a result of an experience of more than ten years with this class of apparatus, the confident statement can be made that the life of the machinery is safely within the limits of average depreciation as applied to manufacturing equipment. The first installation with which the writer was connected twelve years ago is in successful operation to-day. I was informed early this year that one conveyor belt in it, which in service was exposed to difficult conditions of heat and wear, ran for eleven years before requiring replacement.

Another system which has been in operation over nine years, in which all of the original apparatus has been and is now in continual use, save annual replacements of portions of the distributing sand conveyors, and shows to-day every indication of ability to carry on its functions indefinitely. There are other systems in use, some of which have been in continuous operation at full capacity for more than twenty years, so that from the mechanical and structural view-point, there can be no doubt that successful apparatus can be built for the service.

The fact that the above mentioned plants have been operating successfully for years refutes the argument often advanced that with the continuous system the eggs are all in one basket and the fear that when anything stops the whole plant must stop, and considerable loss result. The fear is an idle one, in the first place in a properly designed system everything need not stop when any one function stops. In such a system each operation is allowed enough capacity in material, space and time to enable it to proceed for a considerable time during any stoppage of the other

operations. Any operation can therefore lay up a small surplus of production should there be any delay to the others. When all are again in complete operation after any temporary stoppage the apparatus will run for a short while at maximum loading until the average condition is again attained.

It has already been indicated from the general life of existing apparatus that with a properly designed plant no fear of breakdown need exist. Short stoppages occur for various reasons in probably every continuous plant in the country with practically no effect on the volume of production. Five per cent loss of time from all causes is customarily allowed in planning the operating schedule of any system on any particular work, and from experience I would say that this is a very liberal allowance.

It is unfortunately true that a number of unsuccessful attempts to build apparatus for this service have been made by manufacturers of conveying machinery and these failures have created the idea that conveying apparatus cannot be constructed to handle foundry operations without excessive expense in experiment, maintenance and replacement. These failures have been due to a lack of special experience. The record of successful apparatus shows that the problems when properly understood and studied can be solved.

Who Can Use Such a System and What is the Minimum Capacity on Which It Can be Profitably Installed?

The idea is very prevalent that the continuous system can be used only by manufacturers producing but a single product. This is an erroneous idea. I have never come in contact in my experience with a foundry which produces one single thing and that without any variation. As a matter of fact foundries, even when producing but one line of product, have a great variety in patterns and sizes and these varying patterns are as a rule put as far as possible into molds of uniform size.

It is true that the first successful systems were developed to handle a single line of product, probably because it was felt that the uniformity of the castings would render the problem easy of solution. It is doubtful if the designer realizes how great and important was the uniformity of their molds, irrespective of the

kind of castings produced. At any rate it must be obvious that what they have done with a given number and size of molds any one else should now be able to do.

Every foundryman will realize that the variation is not great in the time of making many of the molds in his plant, even though the patterns may vary considerably in magnitude and complication. A glance at his piece-work rates would probably show him, that he has patterns of widely varying size and form for which he pays the same rate per mold, which means that the same number of molds of each pattern are put up per day. For all practical purposes, so far as foundry labor is concerned, these patterns can be considered on an uniform basis. Experience proves, however, that exact uniformity in size and shape of molds is not necessary for the application of the continuous system, as slight variations of form and speed in the mold conveyor enable it to properly handle wide variations in form and number of molds. On the first system with which I had to do, the molds varied 100 per cent in weight and about 40 per cent in time required in making, and these variations were perfectly accommodated by the system. Also there was considerable vaiiation in pattern, so that the apparatus and men were called upon to handle a considerable variety of work.

In considering continuous operation therefore the mold is the unit on which the functions of the apparatus are based.

Accepting then all of the above evidence, the following example taken from experience shows what can be expected of a properly designed plant.

In a foundry recently investigated, operating on a general line of machinery castings, the following comparison exists:

HAND OPERATING CONDITIONS.

Production per day	12,000 molds
Space occupied	18,000 sq. ft.
Days run per year	300
Molding machine operatives	112
Average production per molding machine hand per day	108 molds
(NOTE.—Maximum product, 209. Minimum product, 62.)	
Average foundry loss	5 per cent
Average earning per day of molding machine hand	$2.47
(NOTE.—Shaking out, tempering and cleaning up is done by a separate laboring gang with one laborer to six molding floors.)	

Average cost per mold, including cost of laboring gang	$0.0259
Average cost per operative of individual equipment, such as molding machines, bottom boards, flasks, bands, weights, etc.	$225.00
Total cost of above individual equipment	$25,200.00
Heats per day	2

Continuous Operating Conditions.

Note: Since two heats per day are run in this foundry, the floor space is more advantageously used than with one heat per day, and the saving in floor space is about one-third instead of one-half.

Space occupied	11,500 sq. ft.
Production per day	12,000 molds
Cost of conveyors, motors, hoppers, etc., installed including power plant	$35,000.00

Comparison of Operating Costs.

From experience in this general character of work, there should be an average increase in efficiency in this plant by continuous operation of 40 per cent since the present methods are low in efficiency. This represents a decrease in labor cost per mold, taking due account of laboring gang and other assistance, of $0.0074 per mold.

12,000 molds per day equal	$88.80 per day
Taking account of previously mentioned 5 per cent loss of running time, this would yield 285 days running time per annum.	
Total labor saving per annum	$25,308.00
Saving in fixed charges on floor space saved at 12 per cent per annum (18,000 − 11,500) × $2.00 × 12 per cent	1,560.00
Saving in fixed charges on individual equipment saved at 20 per cent per annum. $25,200 × 40/140 × 20 per cent	1,440.00
Saving in foundry loss per annum at ⅓ of 5 per cent is ⅓ × 5 per cent × 1,200 molds × (.0259 − 100 per cent fixed charges) × 285 days	3,312.00
Total savings per annum	$31,620.00

To be deducted from this will be operating charges as follows:

Interest and depreciation at 20 per cent per annum on investment of $35,000	$7,000.00
Power	2,750.00
Repairs and replacements	800.00
Total annual charge	$10,550.00
Net saving will be therefore $31,620.00—$10,550.00	$21,050.00
This represents on the investment in apparatus of $35,000.00 a percentage of	60 per cent

Should it be found necessary to build an entirely new casting shop adjacent to a present foundry plant the building and equipment cost would be somewhat increased and may be assumed as follows:

Floor space 11,500 sq. ft. at $2	$23,000.00
Individual equipment 100/140 × $25,200	18,000.00
Conveyors, motors, power plant, etc.	35,000.00
Cupola and miscellaneous apparatus	9,000.00
Total investment	$85,000.00
Hence the $21,050.00 savings represents on the investment in a new casting plant	24.76 per cent

An interesting question of course is, what is the minimum number of molds on which this apparatus could be profitably operated?

Assume that a foundryman would not be willing to install any apparatus which would return him a smaller average saving than 10 per cent on his total investment; then if the apparatus can be put into a present existing plant which would involve $85,000, less the cupola and miscellaneous apparatus on hand amounting to $9,000, the investment in the plant would be $76,000, and we have the following charges:

10 per cent of $76,000.00	$7,600.00
Interest and depreciation charges as before	7,000.00
Due to smaller output power would be 80 per cent of $2,750.00	2,200.00
And repairs 90 per cent of $800.00	720.00
Gross saving which must be made	$17,520.00

Then since $31,620 is the gross saving on a product of 12,000 molds per day, the number of molds necessary to make a gross saving of $17,520 is

$$\frac{17,520}{31,620} \times 12,000 \text{ or say } 6,650 \text{ molds per day,}$$

a production of 6,650 molds per day would therefore be the rate of operation of a 12,000 mold apparatus still returning 10 per cent on the investment.

It is obvious that an apparatus designed for about 5,000 molds would cost considerably less than $35,000 and its repairs, housing and power costs would also be less than the figures previously given and the saving to be made would be considerably more than 10 per cent.

It is beyond question that the experimental period of this method of working can reasonably be considered as ended. It will be found that there are enough systems in successful use, extending over a long term of years, to warrant the belief that there is no difficulty in designing apparatus for handling any particular product. I believe from experience and study that the foundryman who is making upwards of 5,000 molds of fairly uniform size per day at any efficiency less than 50 per cent (and this includes practically all who are using hand methods), will be behind the times and unable to compete if during the coming five years he does not equip his plant for operation in this way. He is in fact losing money to-day, as the foregoing figures show.

"ABOUT SHERARDIZING."

By Thomas Liggett, Jr., New Castle, Pa.

While the subject of this article is "About Sherardizing," I do not think it will be diverging too far if I say a few words about cleaning castings. There are several methods of removing the silica coating—the oldest is that of pickling with hydrofluoric acid. While this method has its advantages it also has its drawbacks—the worst feature of using acid on castings is that if there are any imperfections on the surface the acid gets into them and it is almost an impossibility to remove it. The manufacturer is never sure that the acid has been neutralized, and the result is that to all outward appearances the acid is removed, but it is not very long until the coating is destroyed. Again, if the casting has a high plumbago face the acid will not remove this substance and the clean iron surface is not exposed. Sand or shot blasting is fast displacing the pickle method and is much safer as there are no acids used. The surface of a sand-blasted article is absolutely clean and it has a uniform appearance. Tumbling and water rumbling-barrels are used to some extent and give very good results.

In the early part of this century Dr. Sherard Cowper-Cowles was doing experimental work in case-hardening with a great many different substances. During his experiments he procured some "blue powder" or zinc dust. He carried out the case-hardening operation at a temperature below 788° F., or the melting point of zinc. After the material and zinc dust had become cool he took the material out and found that it had a zinc coating. This was something entirely new, *i. e.*, a piece of metal taking a zinc coat at a temperature below the melting point of zinc. After very thorough and exhaustive tests, it was found that this coating gave the underlying metal better protection from corrosion than the well known hot or electro galvanizing, and patents were taken out in all the principal countries of the world. Realizing that this new process of galvanizing, known as "Sherardizing" (taking its

name from Dr. Cowles' given name), was of commercial value, the United States Sherardizing Company was formed, whose business it is to exploit the process in the United States.

The apparatus necessary to install a sherardizing plant is somewhat varied. By this I mean the plants are built to treat different classes of material. For instance—a plant designed for bolts, nuts, small castings, etc., would not be suitable for pipe. The essential apparatus necessary for a sherardizing plant is an oven large enough to receive the retorts, and the retorts are built to receive the material to be treated in the most economical manner. The largest retorts in use to-day are used by the Mark Manufacturing Company of Chicago. They are twenty-six inches in diameter by twenty-three feet long and are designed for merchant pipe. The number of drums or retorts which are used at one time depends on the daily requirements, and the ovens are built accordingly. The retorts are loaded with material and zinc dust or dross and run into the oven, and heat is applied. Any of the common fuels will answer. The only thing to be sure of is that the oven has an even temperature. The retorts are left in the oven for a given length of time at a constant temperature and then removed. When they can be handled they are opened and the material and dust are dumped on a screen or grating. The dust falls through and is ready to be used again and the material is finished, being covered with a continuous even coating of zinc iron alloy, with a very thin layer of metallic zinc on the surface.

No matter how irregular the shape of the material may be, it has a uniform coating and every letter or thread is reproduced, which is not the case in either electro or hot galvanizing. In electro galvanizing the hollow places are not coated, and with hot galvanizing threads or hollows are filled and flaws are covered.

The zinc dust which is used in the process is a secondary product from a zinc smelter and is recovered in the flues. The dust is composed of from 85 per cent to 92 per cent metallic zinc, about 7 per cent zinc oxide, and some other impurities which are not in sufficient quantities to work any injury. Zinc dross, the material which settles at the bottom of a hot galvanizing kettle, can also be used instead of dust and it has its advantages. Pulverized zinc is used to keep the dust of a constant metallic zinc content.

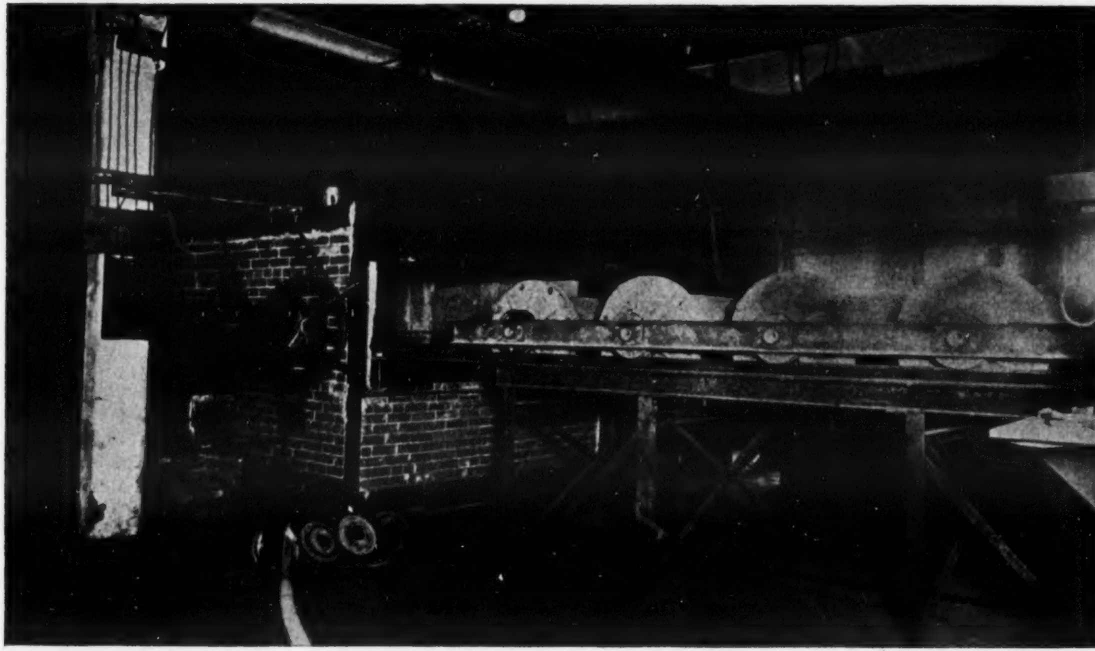


FIG. 1.—OHIO SHERARDIZING COMPANY. SHOWING OVEN AND DRUMS.

To date there have been several theories advanced as to the action which takes place in the drums during the process. Some authorities in England and a well known authority in this country persist in referring to it as the vapor process. This theory is absolutely without foundation, for if there is material in the same drum that is of a different thickness, it is found that the thinnest or lightest material has a heavier coating than the larger material. Now if this was a vapor process the heavier objects, which are the cooler, would have the heavier coating. Again, if a vessel is taken and a casting and zinc dust placed in it, and then the casting is moved around so that there is a cavity of 1000th inch formed and then try to sherardize it, it is found that the casting is only coated where it is in contact with the dust. Now if this was a vapor process the vapor would certainly travel this short distance. We do know that zinc and iron when heated slowly together have an affinity for each other, and some of the authorities claim that this affinity is produced by a very slight magnetic action.

The following facts have been demonstrated:

First.—If the metallic zinc content in the dust is kept constant we will get on the same class of materials equal weights of coating, under the same temperatures and time of treatment.

Second.—Zinc does not begin to deposit until the material has reached the temperature at which magnetic oxide of iron appears.

Third.—That iron which oxidizes with difficulty, sherardizes with difficulty.

Fourth.—The coating is a true zinc iron alloy. I believe that the magnetic oxide of iron which forms on the material is reduced to metallic iron by contact with zinc, which alloys with the excess zinc and exactly replaces the film of magnetic oxide that was first formed.

Dr. Cushman, in a recent paper that has been very broadly circulated, claims that he has found an average of 30 per cent iron in the sherardized coating. This is contrary to our experience. It has been found that the coating is a definite alloy and carries from 8 to 12 per cent of iron—this is known as $FeZn_{10}$. Zinc thoroughly saturated with iron does not contain more than 12 per cent iron. The composition of a sherardized coating contains an average of 10 per cent iron and 90 per cent zinc, while the hot

FIG. 2.—OHIO SHERARDIZING COMPANY. UNLOADING DRUM, DUST BIN, AND LOADING DRUM.

galvanized coating contains 94 to 95 per cent zinc, and the electro-method is practically 100 per cent zinc. The zinc iron alloy being a definite homogeneous alloy has a definite melting point of 1260° F. against 788° F. for zinc. This, under some conditions, is very valuable.

The principal factors that are necessary for a protective metal coating are: (1) Continuity and adherence of the coating; (2) Durability of the coating metal; (3) Galvanic or electrical potential of the coating with respect to the underlying metal.

The continuity of the sherardizing coating, when properly applied, is equal to and in the majority of cases superior to the hot galvanized. While it is true that under the microscope the zinc iron alloy shows cracks or fissures, these are of such minute dimensions that nothing can get through to the underlying metal. The adherence of this alloy is very tenacious and is shown by the fact that a piece of sherardized material having some of its coating ground off and exposed to the weather for over two years, rust had not crept between the alloy and the underlying steel. This is not the case with either electro or hot galvanizing. It is also a very valuable property, especially on fittings or castings, as the coatings very seldom are uninjured by the time they are erected.

The durability of the alloy coating is great, although it is a little more brittle than pure zinc and has a slight tendency to flake if bent through a sharp angle. The metal which is exposed after the flaking is still resistant to corrosion, and shows that the underlying metal is not exposed. The resistance of the alloy to corrosive agencies is much greater than with the zinc coatings.

Sherardized hot galvanized and electro galvanized articles were subjected to a 20 per cent solution of sulphuric acid. The hot galvanized and sherardized articles had the same weight coating and the electro galvanized were somewhat lighter. The results show that while the sherardized coating has more iron in it than the hot galvanized, it will resist corrosion over three times as long as an equal weight coating of hot galvanizing. This is practically the same result that has been determined in England. Dr. Hinchley, of the Faraday Society, has determined that one-half ounce of sherardized coating per square foot is equal to one and one-half ounces of hot galvanizing. The claim that pure metals are more resistant to corrosion than impure metals is borne

out by the above figures, as the alloy, which is a definite homogeneous compound, and pure, in that it behaves as a single metal, is more resistant to corrosion than the hot galvanized coating. The reason for this is that the impurities in the latter are not alloyed together and consequently form local couples.

A metallic coating to be protective must be electro positive to the underlying metal. While there are several "electro positive to iron" metals, zinc is the only one that has been found commercially useful. Some authorities claim that the more electro positive a metal is the better protection it gives, but this is disproved, as metallic calcium or sodium are not possible protective metals, yet are much more electro positive to iron than is zinc. This galvanic property becomes useful when the coating is broken and the underlying iron is exposed to corrosive agents. The surrounding protective coating becomes the anode and the galvanic current flows from the coating to the exposed iron, which is the cathode. It is this cathode current which prevents the corrosion of the iron. A coating which protects galvanically does so at its own expense, as the corrosion takes place at the anode. The more electro positive a metal is the more current flows and consequently the corrosion will be faster. Therefore the nearer the potential of the coating metal is to the underlying iron the slower will the protective coating be corroded. From this view the sherardized coating is more resistant to corrosion than either the hot or electro galvanizing as its potential is about .25 volts compared to .53 for hot and .502 for electro galvanizing. The copper sulphate or Preece test also shows that the zinc iron alloy of the sherardized coating is more resistant than either the hot or electro galvanizing. Dr. Burgess of the University of Wisconsin has made some very careful investigations on the rate of attack on zinc and zinc iron alloy coatings and found the following:

Method of Treatment.	Loss gr. per sq. in. per dip.
Hot galvanizing	.0135
Electro galvanizing	.0131
Sherardizing with dust	.0109
Sherardizing with dross	.0082

The appearance of a newly sherardized article varies from a satin finish to a dull zinc color—this variation is due to several

causes. The main thing that determines the color is the appearance or finish of the casting before treatment; the brighter and more uniform the color, the better appearance after treatment (this is one reason sand blasted material looks better than that which is pickled). Also if there is any quantity of air in the drum the material has a tendency to have a dark finish. Similarly if the drums are rotated constantly, the material is darker than if the drums are rotated intermittently. When newly sherardized material is exposed to the weather it generally takes a yellowish color. This is due to the iron that is in the dust on the surface of the casting and does not come from the casting. The first good rain will wash off this yellowish color and the coating gets darker until it has finally taken a slaty black appearance—this is the final stage, and material with this appearance has shown no signs of corrosion.

As is well known, paint or enamel will not adhere to either hot or electro galvanizing with any permanence. Due to the rough exterior of sherardized surface, paint and enamel adhere firmly to the surface—this in some classes of work is a very valuable feature.

In the hot galvanizing process it is necessary to keep the kettle hot twenty-four hours a day even though it is run on a ten-hour turn. It is necessary to replace the kettle about every twelve to eighteen months. While this is not a large item of expense, it causes production loss and upsets the routine of the shop. The process is very wasteful as there are large losses due to the spelter vaporizing—loss on skimmings and dross. It has been found that these losses average 30 per cent of the charge, and with spelter at seven cents a pound or more they are quite an item in production cost.

In the operation of the hot galvanizing process there are several steps that are wasteful and harmful to the casting. After the casting has been cleaned it is dipped in a flux and allowed to dry (in some cases). It is then plunged into the molten zinc, temperature of which varies from 900 to 1000° F., or more. The casting is left in the bath until its temperature has been raised to that of the bath, so that the coating will be smooth, and then removed, and generally plunged into cold water. The result is, as Dr. Richard Moldenke says in his book, "The Production of Malleable

Castings," a hard or crystallized casting in which the temper carbon has gone back. This also reduces the strength of the casting. The amount of zinc which the casting takes on cannot be regulated and in most cases there is an excess.

The electro galvanizing is little used by foundries; while for some classes of work it gives satisfactory results, it requires expensive machinery and for first class protection against corrosion the cost of production would be commercially impossible. This cost is due to high current expense and cost of zinc. Also it requires extreme care in handling the castings before treatment as any grease or oil or other dirt prevents a deposit of zinc. If the casting has a very irregular surface the hollow places fail to take a deposit and consequently are not protected. The only advantage the electro process has over the hot is, the zinc being an electrical deposit, there are no impurities in the coating to form local couples.

The sherardizing process, while the apparatus is a little more costly to install than the hot process, is much cheaper than the electro-galvanizing, and once installed has practically no maintenance charge. Establishments are still using the drums and ovens that were installed four or five years ago and from present appearances are good for four or five years more. As the deposit depends on time and heat, the excess deposit which cannot be controlled by the hot galvanizing is avoided, which is quite a saving. As there are no fumes, skimmings, or dross, this waste is eliminated. The loss of dust in a well designed plant averages from 1 to 2 per cent. As zinc dust has a low factor of heat conductivity it is impossible to subject the castings to sudden changes of temperature—this avoids crystallization and cracking of castings. While there have been no great number of tests made to determine the effect of hot galvanizing and sherardizing on the strength, the indications are that while the hot galvanizing materially reduces, the sherardizing has in some cases slightly increased the strength as compared to the plain casting. In the case of fittings and castings, screw and thread work does not need re-cutting after the treatment, as the threads and surfaces are reproduced—this gives an entirely rust proof surface.

Finally referring to the cost of sherardizing castings, it has

been found that the saving is from 25 to 40 per cent over hot galvanizing—this saving is due to less fuel being used per pound, less labor being required for equal tonnage, less zinc required for equal protection. The loss of material is practically nothing. Maintenance on plant is very low and no loss of work from cracking and crystallization.

RECOVERY OF SHOT IN SMALL FOUNDRIES.

By S. A. Capron, Westfield, Mass.

In the items that make up the shrinkage of pig iron melted to castings produced, the iron lost in recovery of the cupola bottom and the shot and fines lost in the foundry sand, one finds a large percentage of the total metal lost.

The development of electricity has brought about processes which gather up this lost material with the least possible amount of handling by means of electric magnets and flat conveyor belts. The method herewith described uses a device consisting of two sets of belts running in parallel planes; one travels through the magnetic field; the conveyor belt has its top running in the same direction as the lower side of the belt traveling through the magnetic field and at a variable distance below, and stops at about six inches within the magnetic field. Both the conveyor and magnetic belt are 12 in. wide. The former has a speed of approximately 200 ft. per minute, and the latter 300 ft. per minute.

The magnetic field is about twenty-four inches long, so that there is a very generous space for the non-magnetic material to fall, even with the conveyor belt traveling at a rapid rate.

The device in question has a capacity of about two and a half yards of material per hour with such material as chaplets mixed with the core sand. Recently a bin of this material was put through the machine in ten hours, obtaining thirty tons of chaplets, and separated as waste four cubic yards of sand and stones.

When handling the material from the bottom drop, the material is gathered up from under the cupola, all the material which passes through the two-inch space of the forks is put into the hopper of the separator and all the small iron is gathered up, leaving the sand and coke to fall on a one-inch mesh screen, recovering the good coke which is taken to the boiler room and the material passing through sent to the dump.

FIG. 1.—FRONT VIEW, SHOWING FEED HOPPER, MAGNETS, ETC.

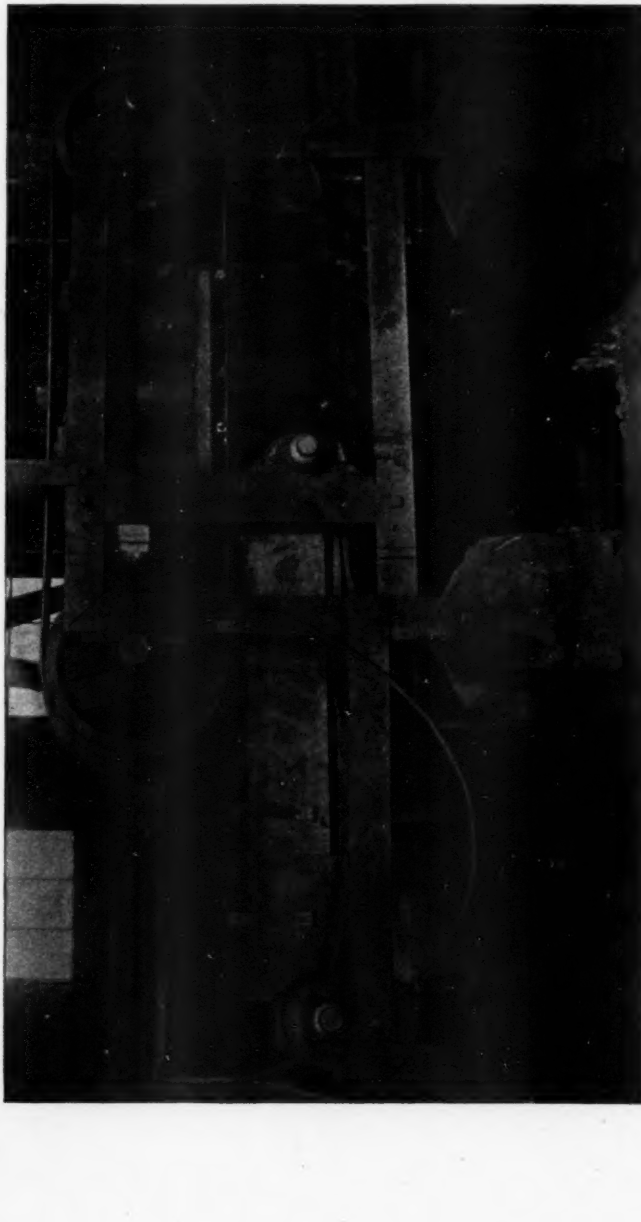


FIG. 2.—REAR VIEW.

The large material is put through the cinder mill and the recovered shot is then put through the electric separator. Two tons of material recovered from the cinder mill was put through a test and it was found that the separator threw out twenty-six per cent of non-magnetic material by weight and thirty-one per cent by bulk. One can readily see the noticeable effect this would have on the working of the cupola when remelting this material.

One of the very probable causes for a better working in the cupola of this separated metal is the fact that the iron recovered is in very irregular shapes which it took as it fell into the sand on the foundry floor, and the spongy formations of that which is recovered from the bottom drop as it chilled about the irregular pieces of coke. If this had been put through cinder mills the pieces would have been crushed and tumbled into spherical shapes, which make them much more likely to fall between the spaces of coke in the cupola without coming in contact for a long enough time with the hot gases of the melting zone.

There is a very large possible variation in the construction of the belt encasing the magnetic field for different purposes. It can be made with fingers protruding from its surface, reaching down to the mass of the material traveling on the conveyor belt. These fingers can be made to be either magnetic or non-magnetic, and thus pick up the material weak in magnetism.

The device is one which will appeal to the foundries whose products are not large enough to afford the more expensive installation of cinder mills, but still must save as much of their by-product as possible with the least amount of labor and overhead expense of machinery. The machine is driven by a three-inch belt at about a hundred revolutions and its electrical consumption is about two amperes at 110 volts, which would ordinarily cost about twenty to thirty cents per day of ten hours. It has no delicate electrical appliances or connections and its mechanism consists of four horizontal shafts connected by the two belts previously described.

THE IMPORTANCE OF DISPATCHING IN THE FOUNDRY.

By C. E. Knoeppel, New York City.

Success, for which we all strive so mightily, is a matter of *adjustment*—an efficient arranging of the forces with which we work. We all play a game in life, and like as in any game there are the winners and the losers. We must all admit, however, that this adjustment is not altogether a matter of chance, a something over which we have absolutely no control, for the study of any success, whether the winning of a battle, the erection of a skyscraper, or making a business pay, will show that something preceded this adjustment which resulted in the absence of failure. For want of a better term let us call this something—*conception*.

Every act, every happening, is based on these factors—conception and adjustment. Take this convention for example. Down to the very last detail, everything has been worked out, following a series of conceptions, and we are all impressed by the excellence of the adjustment. Imagine the condition that would result if everything had been left until the first session. Instead of hopeless confusion, lack of co-ordination, unintelligent plans, you see order, arrangement, smoothness—a successful termination of months of conceiving and adjustment.

Is there any difference when it comes to the operation of your foundries? Is adjustment what it should be without the right kind of conceiving? Is not it generally the case that the better the conception the better the adjustment, which results in your success? Let us then for a few moments discuss this matter of conception in its relation to the conduct of your business. It may even prove of value, for there never was a time when modern industrialism was as complex as it is to-day. It seems that more thought and energy is demanded of us all in order to keep in the front. If there is a lessening of activity for a time it results in a poor adjustment, the effect of which is felt in the business.

Hull in his excellent treatise on "Industrial Depressions" tells us that the industries of a nation are nothing more than an aggregation of the acts of individuals, and that the motive which gives origin to the industries is the instinctive desire for gain. As regards the particular concerns you may be operating or responsible for, the acts of the individuals under you, from your superintendent to laborers, determines to a great extent your realization of your desire for gain.

If all of the acts of all employed in a plant could be passed for a single day over a moving picture screen, the result would no doubt be most surprising and convince all that the adjustment of these acts, day by day, is a matter of prime importance. It would establish beyond question the absolute necessity for proper conception previous to action. How many foundries are there where the practice is to arrange *in advance*, in a careful and scientific manner, the co-ordination of the work to be done the next day and the next week; where the details as regards adjustment are so mapped out as to insure working as near as possible to the co-ordination planned?

The best way for you to answer this question is for me to paint for you a mental picture of what this all means in a practical way. Supposing that on a certain morning you should step into your foundry at starting time and find that on all floors the sand was free from gaggers, properly tempered and ready for use by the molders—that the patterns had been distributed and were in flasks on the floors ready for the molders to begin work—that each molder was employed on that class of work for which he was best fitted to perform—that where pit work was to be made, the pit had been dug and shaped for the pattern or sweep—that there was the right distribution of molders' helpers and laborers—that during the day as cores were needed, they were supplied the molders in advance of their requirements—that you noticed that in no case did molders have to discontinue work because facing or nails and other like materials were lacking—that in cases where flasks needed special barring, you noticed that the flasks on the floors contained either new bars or such cutting in the old bars as would accommodate the patterns—that as molders completed certain jobs, other jobs were ready in advance with patterns and flasks provided—that noticeable delays were reduced to a minimum—

that rush orders had been provided for—that the men were working on the important jobs in the order of their importance—that all foremen not only knew what was going on but what the coming procedure was going to be—that this was the order of things for the whole day for all the men and that *day in and day out this efficient working was the rule and not the exception.*

An excellent but impossible picture, you say? It is a picture that outlines an adjustment as it should be and fortunately *as it can be, if taken as an ideal, accepted as possible, and all efforts concentrated on achieving these results.*

If a student at college should listen to a lecture here, there and elsewhere, with no apparent aim in view; if he attended classes as fancy might dictate; if he blindly selected the subjects that he thought it would be well to study, it needs no imagination at all to see that he would leave college with a mighty poor training with which to tackle the big game ahead. You would never consent to this at all if the young man happened to be your son. There would be a decision as regards the kind of training, following which there would be a selection of the particular university. Arrived on the ground the young man would find subjects, lectures and classes outlined for him with ample time allowed for study and recreation periods. What do we have here but conception and adjustment?

Consciously or unconsciously we marvel at the efficiency of our modern passenger train service. You take the Twentieth Century Limited from New York to Chicago and in eighteen hours you travel nearly a thousand miles. A smooth-running proposition, and yet a thousand details are considered. Details as to track, roadbed, switches and curves, bridges, cars, engines, crews, stops, changes, schedules have all been co-ordinated that speed and safety—for gain—might be the result. More evidence of conception and adjustment with nothing left to chance.

The new Woolworth Building in New York is the latest addition to the gigantic office buildings. Was everything left until the day they broke ground? Never. Everything was anticipated. Strength of materials, stresses, kind of materials, foundations, plans and specifications, floors, decorations, inspection and many other things were all merged so that when work was commenced

it could follow logical lines. Again we see conception and adjustment at work.

What is conception but the *plan* and *ideal* with which to start? What is adjustment but the arrangement which co-ordinates the various details, to the end that the ideal may be attained? Borrowing from railroad practice the word "dispatching" to mean co-ordination and we have *planning* and *dispatching* as synonyms for *conception* and *adjustment*, as the shortest distance between two points.

You are in business for gain. You make castings for others, whether directly or indirectly. In proportion as you eliminate waste and lost motion you satisfy others and profit thereby. The only consideration therefore that concerns you, is not that dispatching is a valuable thing or absolutely worthless, but what it is and how you can get practical results from it.

How then are we to control the acts and so arrange the details that co-ordination may be at maximum efficiency? In the first place our conception or "ideal" should be—

1. No man should do any work that can be performed as well by another, with less skill and at less expense.

2. Work should be assigned to the men best fitted to do it and not given out simply because they have nothing else to do.

3. Sufficient work should be assigned in advance to insure keeping the men employed during the day.

4. The importance and availability of all work should be considered.

5. Selection and assignment of work should be the result of a getting together of those who are responsible for the management of the plant.

6. Waste time and lost motion should be eliminated whenever found.

The above constitutes an excellent ideal which every foundry should work to, a conception that is not only practical but necessary to the efficient adjustment of the following elements:

1. The workmen.
2. The orders.
3. The patterns.
4. The cores.
5. The flasks.

6. The rigging.

7. The incidental accessories, such as nails, gaggers, sand, chaplets, etc.

8. The pouring.

9. The taking out of work.

10. The cleaning.

In considering dispatching there are two things to keep in mind:

1. The making of the plans.
2. Execution according to the plans.

And if proper attention is given to them, faulty conditions will be reduced to a minimum, if not entirely eliminated, for their assumption is—*no job is ready until everything is or will be ready for the job*—a most important consideration.

Planning is made up of six important elements:

(*a*) What is to be made.
(*b*) Who it is to be made by.
(*c*) Where it is to be made.
(*d*) When it is to be made.
(*e*) How it is to be made.
(*f*) With what it is to be made.

And you can readily see that if every job is forced through this kind of an advanced and well regulated analysis, considerable good is bound to be the result.

Execution is composed of the following elements:

(*a*) Knowledge of the plans made.
(*b*) Preparations for carrying out the plans.
(*c*) Carrying out the plans as per schedule.

As the desire is to harness planning and execution so as to make an efficient working arrangement, the order, which is our starting point, should receive some attention; so that we may know something regarding its availability. The following test is a good one:

1. Are the patterns and core boxes as per order?

2. Are they ready for delivery into the foundry?

3. Are there flasks to accommodate the work?

4. If not, will they have to be made or can others be altered to suit, and if so what work will be necessary?

5. What will the job take in the way of rigging?

6. Is the rigging in hand ready for use or will it have to be made? If so what work is necessary?

7. What will be necessary in the way of rods, gaggers, clamps, etc.?

8. How long will it take to get the job ready?

Until an order can pass this test it should be classed as *not available*, and under no consideration except extreme urgency should such a job be started. A rule of this kind will prove of extreme value in any foundry.

The next point to consider is the promise. One should be made for each job in order that the work can be traced with reference to a time of completion. Promises should never be made, however, before the availability of the work has been passed upon. Such promises are never dependable and the time and energy in making them is usually wasted, as a great many know.

An order arrangement that will consider these two points—availability and promise—should therefore be built up around the following points:

1. It should admit of a quick and ready reference.

2. It should show availability or non-availability, *at a glance*.

3. It should show anticipated delivery dates.

4. It should notify pattern storage what is wanted in the way of patterns, sweeps and core boxes.

5. It should enable pattern storage to notify foundry as to condition of the items called for.

6. It should show reasons why work is not available.

It is evident from the above that we are now in possession of three valuable items of information:

1. We know what is not available and why.

2. We know when work becomes available.

3. We know when work is wanted, or the promise date.

With this knowledge we can commence the task of getting the work under way according to the following general outline:

1. The details should be in charge of a committee comprising foundry foreman, his assistant, core-room foreman, as well as the flask and labor bosses.

2. The work should be undertaken as early in the day as possible so as to allow ample time to get in readiness whatever may be necessary to start the jobs properly.

3. The work being made in the shop and the men engaged in it should be carefully sized up.

4. Patterns, sweeps and core boxes covering jobs that are to be started should be laid out in pattern storage, in space that will enable those planning to get at them easily.

5. A means should be provided for listing the work as planned.

6. In selecting the work, the six considerations under *planning* should receive attention.

7. If more than one job is selected for a man or the floor; attention should be given to the order in which they are to be made, in order to know what to get ready first.

8. The core-room foreman should note carefully the selections made so he may have the important core-boxes sent in first.

9. The flask boss should note what flasks will be necessary for the various jobs that are planned.

10. The labor boss should note what rigging will be necessary so that he can get at work as soon as the planning is over with.

11. A means should be provided for marking the patterns with the numbers of the men who are to make them.

12. The pattern storage should set apart from the patterns available, those which have been selected for making.

With the above consideration given to the planning, we can next consider the element—*execution.* As was previously pointed out, this is made up of three steps—knowledge of the plans made, preparations for carrying them out, and carrying out the plans as per schedule.

Knowledge of the Plans Made.—Any plan for betterment in order to produce results must take into consideration the importance of a general understanding of things. Several persons may be involved and unless the relation of each to the whole scheme of things is clearly outlined, there is certainly going to be confusion, the same as there would be confusion on a railroad (or even worse, a serious wreck) if there existed any doubt as to a correct understanding of an order. With this in mind, the idea of presenting the plans to those interested, in some convenient form, in writing, for reference purposes, is therefore self-suggestive. This should be done as soon after the planning as possible in order to give those concerned the time to arrange the proper procedure.

Preparations for Carrying Out the Plans.—An analysis of this will show that it subdivides into the following:

1. The patterns.
2. The cores to be made.
3. The flasks to be located, repaired or changed.
4. The rigging to be brought in and the necessary changes made.
5. Special features looked into, as for instance special gaggers, rods, clamps, etc.
6. Changes in conditions to facilitate the new work coming in.
7. The work at night.

As to each of these seven divisions the following can be roughly outlined:

Patterns.—Small patterns should be brought into the foundry on the afternoon previous to making and placed in the racks for the men. Large patterns should be brought in towards night and arranged in some convenient place from which point they can be easily handled.

Cores.—As soon as possible after planning, the core-room foreman should see to it that the most important core-boxes are brought in so that his force can begin on them without delay. The balance can follow in the order as scheduled.

Flasks.—The man in charge of the flasks should ascertain what is necessary to take care of the work coming in. Flask parts that have previously been made should be assembled; those needing chucking should be promptly attended to, the necessary patterns to be taken from the pattern storage for this purpose. If repairs are needed they should be made at once.

Rigging.—Rigging in the way of plates, rings, arbors, etc., should be brought in and the necessary changes made so that they will be available when wanted.

Special Features.—If special gaggers, rods, etc., will be needed, they should be made on the day previous, so as to be in readiness when wanted.

Conditions.—Changes in conditions should not be slighted. A job may take a special mix of sand; a pit may have to be dug; a large amount of heap sand may be needed; brick may be used, or something else varying from the ordinary method of procedure

may have to be done, and the time to do it is certainly not when the molder is at work.

Night Work.—The man in charge of the night force should be informed as to his share of the work necessary to carry out the procedure as scheduled. Castings should be taken from the sand to the cleaning room; gaggers removed from the sand heaps and placed on the back of the floors; sand tempered and put in condition for use by the molders in the morning and the flasks not needed taken from the floors. Pits should then be dug according to the sizes needed.

Carrying Out the Plans as per Schedule.—This is a subject of vast importance. Planning in itself may be careful and thorough; preparations to carry them out may be up to standard, but unless the actual procedure is one which does things according to the schedule, the results will not be forthcoming. The first hour in the morning is really the most important time in the day. There are a lot of men to be attended to; flasks, patterns and rigging must be distributed and it cannot be all done at once nor to advantage unless there is some organized arrangement. The following is therefore suggested:

1. The night force after the regular night work is done, as outlined, should place on the molders' floors, according to the schedule furnished the night foreman, the various new large flasks that are to be used in which should be placed the patterns. If pits are to be used, the patterns should be placed near them. This will ease the work of the cranes to quite a degree.

2. About a half hour before the regular starting time in the morning, the laboring force, or part of it, should report and distribute the smaller flasks and patterns.

3. As soon as work is begun in the morning, whatever may be necessary in the way of rigging should be taken to the floors.

4. There should be a regular place for all supplies and the knowledge of their location should be in the possession of all.

5. Facing sand (which should be mixed in advance) should be kept at each molder's floor and replenished as necessary before (not after) the men may need some.

6. The labor foreman should carefully watch the needs of the men as to copes. There is no excuse for a molder asking for a cope only to find that it is at the bottom of a pile.

7. The molders should be kept supplied with tools and equipment and should report their needs to the labor foreman.

8. Cores should be furnished the men in advance of their requirements. They should never be made to go for them.

The machinery to handle all this is not as complicated as might be imagined. The fundamental consideration is ***knowledge in advance*** and the details can be taken care of without much difficulty. There should be job tickets or "service cards" on which all information is entered from the orders. There should be large dispatching boards in some central location from which the work of the men can be controlled. This board should reflect the following conditions:

1. What is being made.
2. What should be made next.
3. What constitutes the work to follow and the order in which it should be made.

There should be an entering of starting and finishing time and the number recorded on all job tickets. There should be a written daily schedule covering the work of the men for the following day. There should be a schedule covering the job that will show progress of the order. These are the main considerations that can be built around the principles previously outlined, to make an efficient dispatching arrangement.

The following will show the advantage of the job schedule:

Scheduled			Finished				
Date	No.	Total	Date	No.	Ahead	Behind	Efficiency
3/20	10	10	3/20	5	....	5	....
21	10	20	21	10	....	10	....
22	10	30	22	....	....	20	....
23	15	45	23	20	....	10	....
24	15	60	24	10	....	15	....
25	15	75	25	15	....	15	....
27	20	95	27	5	....	30	....
28	20	115	28	10	....	40	....
29	35	150	29	10	....	65	63.3%
....	....	....	....	95	....	....	....

$$\text{Efficiency} = \frac{95 \text{ Finished } 3/29}{150 \text{ Should be finished}} = 63.3\%$$

As a watch improperly adjusted will fail to keep good time; so will the acts of those under you lead to inefficient conditions if not properly adjusted. What has been here outlined is in line with progress and is a necessary factor if management is to be of the highest type. The foundry should have as good as can be had, and it is hoped that what has been said may assist the foundryman in securing a greater efficiency through *conception* and *adjustment* as applied to his details.

SOME SALIENT POINTS IN THE MODERN STEEL FOUNDRY.

By Samuel R. Robinson, Coraopolis, Pa.

In this paper an attempt will be made to describe the advancement in the different departments of the steel foundry in recent years.

Furnace.

In acid practice the general construction has changed but little from the furnace of ten years ago. In building the usual twenty-five-ton furnace it is now customary to put three rows of brick on the bottom plates and eighteen inches of brick over the chill plates. The corners are not left square, but are "filleted," *i.e.*, they are filled up with brick so as to prevent a breakout at this point. Charging machines are used on all the later furnaces from twenty tons up. If space will not permit their use the furnace is served by a charging crane. The checkers are built independent of the furnace; that is, they do not support the weight of the furnace.

All furnaces are built entirely above ground with the top of the flues on a level with the ground.

The use of 50 per cent electro ferro silicon in place of the 11 per cent alloy is general now; preferably in the furnace, but quite often in the ladle. The writer's opinion is that all additions should be made in the furnace as far as practicable, as the furnace is the proper place to make the steel and not the ladle.

Fuel oil is used extensively; in most cases being atomized with air at a pressure of 45 pounds of oil and 30 pounds of air. The usual plan is to have the pressure on the oil storage tank. Steam as an atomizing agent is very seldom used, as it is now generally known as a mistake to think that there is a gain in heat through its dissociation.

Small open-hearth furnaces are coming into more general

use; that is from five to ten tons capacity. Twelve thousand pound heats are now being made in this type of furnace, making 140 openings of the stopper and requiring one hour to pour. The life of such a furnace should be 500 heats without repairs.

The latest development in small open-hearth furnaces is the Carr furnace, of about two tons capacity, with the entirely new principle of pouring directly from the furnace into the molds. On account of the high temperature obtained this furnace permits of the manufacture of castings of thin section and intricate design. The metal is very pure, as there is no contamination except from the flame which is usually natural gas, although of course producer gas or oil can be used.

Converters.

The accepted side blow practice consists in the use of a lower silicon, say from one and a quarter to one and a half per cent, with a blast pressure of from two and a half to three pounds to the square inch. This is found to give quieter blows and hotter metal.

The biggest factors in successful converter operation are (1) clean hot iron from the cupola, and (2) fast working. Do not skimp on coke, and arrange to run so fast that it will not be necessary to shut the blast off the cupola.

Successful economic operation requires a high degree of skill and strict attention to the little things.

The practice quite often now is to "cut the flame short"; that is to turn the vessel down just before the drop of the final flame and then, without any final addition of iron from the cupola, adding lumps of wet ferro manganese to the converter, and 50 per cent ferro silicon to the ladle.

The old fire brick tuyeres have been replaced by ordinary iron pipes which are rammed up in position with ganister and are left in during blowing; when they burn off they are simply shoved further in and a new piece of pipe placed on the back end.

The vessel is usually lined with silica brick, using nine-inch brick on the bottom, side-arch up to the tuyeres, wedge-brick up to the dome, and key-brick for the dome. Ganister is sometimes used, being mixed with a small amount of fire clay and

rammed around a form. The cupola is lined with brick and usually patched with mica-schist or sandstone.

Chill pig iron is not used to advantage in cupolas under 42 inches inside the lining. For the smaller size cupolas it is better to use sand pig broken into four pieces if possible.

The charge usually consists of 70 per cent pig and 30 per cent scrap steel, although 50 per cent scrap is carried regularly in some shops. In using 50 per cent scrap the metal has to be handled very rapidly as it has not much life in the ladle.

Eleven per cent ferro silicon is used in the cupola at times to bring up the silicon when the percentage of silicon in the pig is low. In fact it is possible to melt and convert a charge of all scrap and 11 per cent ferro silicon without any pig whatever.

Lip pouring is the usual practice with converter steel, although bottom pouring, in a green sand molding shop using match boards and ramming up all work on the floor in regular rows, has many advantages. The usual practice is to use the same ladle with the original nozzle as often as possible, using a new stopper each time. As many as six blows can be poured through one nozzle at times. In some shops the nozzle is changed as well as the stopper after each blow.

The most recent developments in converters are the Tropenas 1,000 pound "Baby" converter, and the "stock" oil fired converter.

The "Baby" Converter.

This type is an interesting proposition for a small shop. Its main advantages are low cost of installation and small outlay for power, and not requiring a traveling crane as a jib crane will handle almost anything met with in such work. The metal is very hot and fluid and is poured over the lip of the ladle.

The Stock Oil Fired Converter.

This type does away with the cupola altogether, melting the charge of pig and scrap in the vessel direct with an oil flame, and when at the required temperature blowing the heat as in regular side blow practice. The point that strikes one immediately is that it does away with the cupola entirely. Very few

people realize the loss in the cupola as ordinarily conducted. The saving of heat by not having to transfer the iron from the cupola to the converter, also the reserve of heat left in the converter from a previous blow, must be quite an item.

The inventor of this process claims that a charge of two and a half tons can be melted and converted in one and three-quarter hours with a fuel consumption of seventy gallons of oil and a power consumption of fifty kilowatt.

The metal can be made very hot and it is very pure, as there is no contamination from the flame.

Molding.

The greatest improvement has been in the direction of a more refractory sand for facing by a careful selection of good silica sand and pure fire clay. Drying the molds is watched more closely and a continuous record of the oven temperature is kept at all times. Recording thermometers for core ovens are now in general use also.

Inspection.

All shop inspection should be in the hands of competent men and all castings should be checked against the blue print and inspected for imperfections before they are put up to the customer's inspector. In regard to the shop inspection by outside inspectors. This is a subject that the writer approaches warily, although he along with many others in the business feels that, to say the least, there is room for improvement both as an aid to the manufacturer as well as the customer.

There at least should be some standard for guidance. For instance, why is it necessary to put test bars on small work such as a body center plate? Why would it not be more satisfactory to pick out at random a few castings and test them to destruction? And then for tensile tests take regular heat bars cast in the same heats as the castings.

The manufacturer has a fear of some present-day inspection, and consequently does not go after business that he otherwise would if he had the information at hand that would show him just what he had to look out for.

One customer's specifications will call for test bars on all castings over 50 lbs. in weight; another on all castings over 500 lbs. in weight. One will call for minimum elastic limit of 37,000 lbs. to the square inch, with tensile strength from 65,000 lbs. to 75,000 lbs; while another will want the elastic limit to be one-half the tensile strength.

The writer would suggest that this association go on record as favoring a standardization of specifications for steel castings, appoint a committee to draw up such specifications and give them the widest publicity among the trade.

ON PATTERNMAKING.

By James Glass, Pittsfield, Mass.

Constructivity.—The mere mention of the work suggests of building a battle-ship or a sky-scraper. To build, is a physical endowment; to build wisely, is a moral attainment; to build correctly and quickly, which means cheaply, is a commercial necessity. The general lack of this constructive quality in workmen is best known to the progressive employer, whether in the foundry or in any other industrial line of action. Nowhere in manufacturing is its influence felt and its usefulness more applicable than in the patternshop.

Until recent years the patternshop has been looked upon as a semi-productive department and the patternmaker as a kind of a half brother to the artist. This attitude of the employer no doubt has brought about the present condition with its lack of individual improvement and certainly has curtailed the patternmaker's value as a productive unit. To get at something that will be mutually beneficial to employer and employee alike we must replace the artist with the mechanic, the impractical with the practical, the æsthetic with the constructive. Let us look along the benches in the patternshop. We find the boy or the man laboring over a drawing. He has formed correct impressions as to the general outline of the work. He has concluded as to the best method of molding, but the construction of the pattern has him guessing. This stay in the progress of operation does not always apply to a big job but very often to the small one, and the mode of construction is the determining factor in the price.

How often have we heard the patternmaker say, "If I had to make that job again I would build it a different and an easier way;" but unfortunately for the employer the same design is seldom used.

I say the mode of construction on a small pattern regulates the cost, and let me give a few simple illustrations in defense of

the assertion. Take a small cap as in Fig. 1. Nine times out of ten the man will lay it out on a small block, saw out what he can on the band saw, and then complete the work carving it out to the desired shape by hand. By constructing it as in Fig. 2 we take full advantage of the saw reducing hand work to a minimum and saving at least fifty per cent in cost.

Another small pattern as in Fig. 3. To lay this pattern out on a piece of wood and dig out by hand what cannot be reached

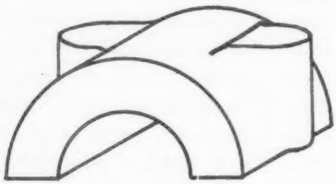


FIG. 1.

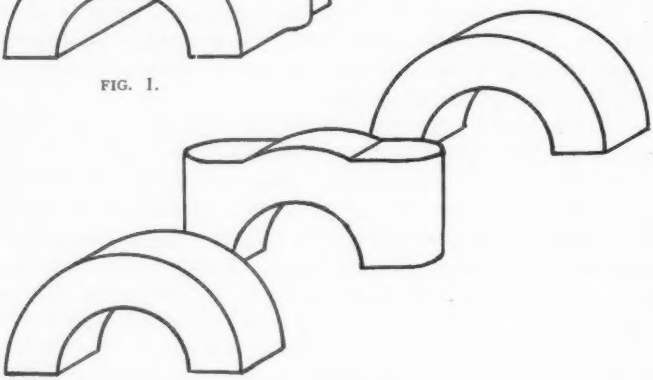


FIG. 2.

with the saw means labor and time; but note in Fig. 4 how near completion by dissecting it and doing the work almost wholly with the machine. The dissecting of a small pattern to facilitate its production does not always weaken it, as some might think, but as a matter of fact more often strengthens it and for the majority of purposes quality of workmanship is not destroyed.

In a bigger pattern, such as an ordinary bedplate, for molding purposes, durability, etc., we have decided to make a box pattern, coring out the inside. The usual mode of procedure on a pattern like this is to get out two frames (top and bottom) to the given

dimensions, half lapping them at the corners, filing in between to the desired shape and height. Fig. 5 shows how in building we may form an enlarged lapp with butt joints, simplifying construction and with a noticeable saving in labor. By gluing blocks in the corners and pieces across the joints inside while building, we have a pattern capable of withstanding any kind of abuse.

These illustrations are elementary to some patternmakers, but the general need of attention along these lines is very obvious to those directly connected with the trade. I have talked of the man who makes every lick count, "the man who makes a good piece of work" with a hundred per cent less time on it than the other men in the shop, and with seemingly less effort—he's the constructive man. This is the man we are all looking for; the

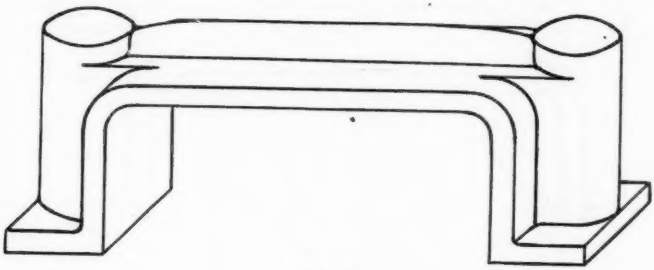


FIG. 3.

kind of workman we want to raise. This is the man who does not have to be told every move to make, who increases production and decreases the cost of supervision. In him we have the evolution of the artist in the patternshop—the builder.

This type of workman is always respected by the boss and admired by his fellow workmen—respected by the broad minded foreman because of his rapid completion of the work entrusted to him, and admired by the men because he is a leader.

But it is surprising how few realize and how seldom the attention is drawn to the fact that this man's master power is due to his natural or acquired constructive ability. It is oftener concluded that his qualities originated in his having worked in a good many shops. While moving around is a help to the builder, adding to his confidence in generalities, it is far from being the

key to his success as a workman. Some men might chase from shop to shop a hundred years and never climb above the ordinary.

Some years ago, while working in the patternshop connected with one of our large plants, I wanted to confer with the foreman as to the method of buildingup a good-sized pattern and approached him with this purpose in view, but met with the response, "If you are a patternmaker you ought to know." It was this indifferent attitude of one whose position warrants assistance rather than rebuff that made me seek the society of Mr. Construction, and

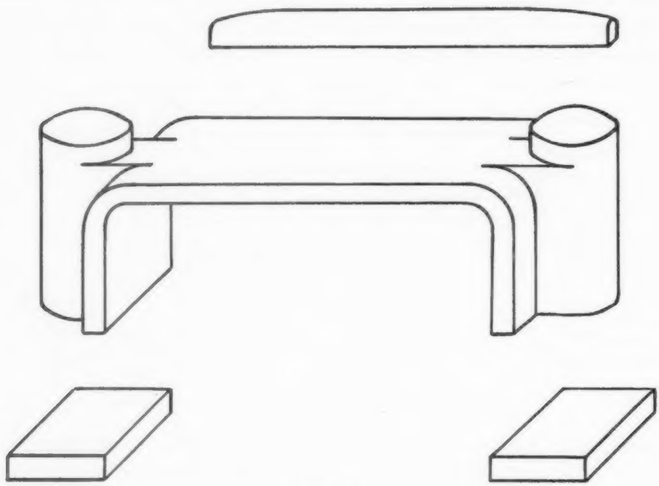


FIG. 4.

believe me he is the most willing and most able consulting engineer of my associates.

"The art of patternmaking!" Why, art is a disguise to talent, taste is the foundation of art, constructivity is a creation of the mind, a ramification of thought. We take our place in the industrial field according to our constructive ability—nations as well as individuals.

Jas. Naysmith, through his study of Euclid (mathematics) developed his steam hammer. The foundryman's success is due to an efficient business structure; the scientist's achievements

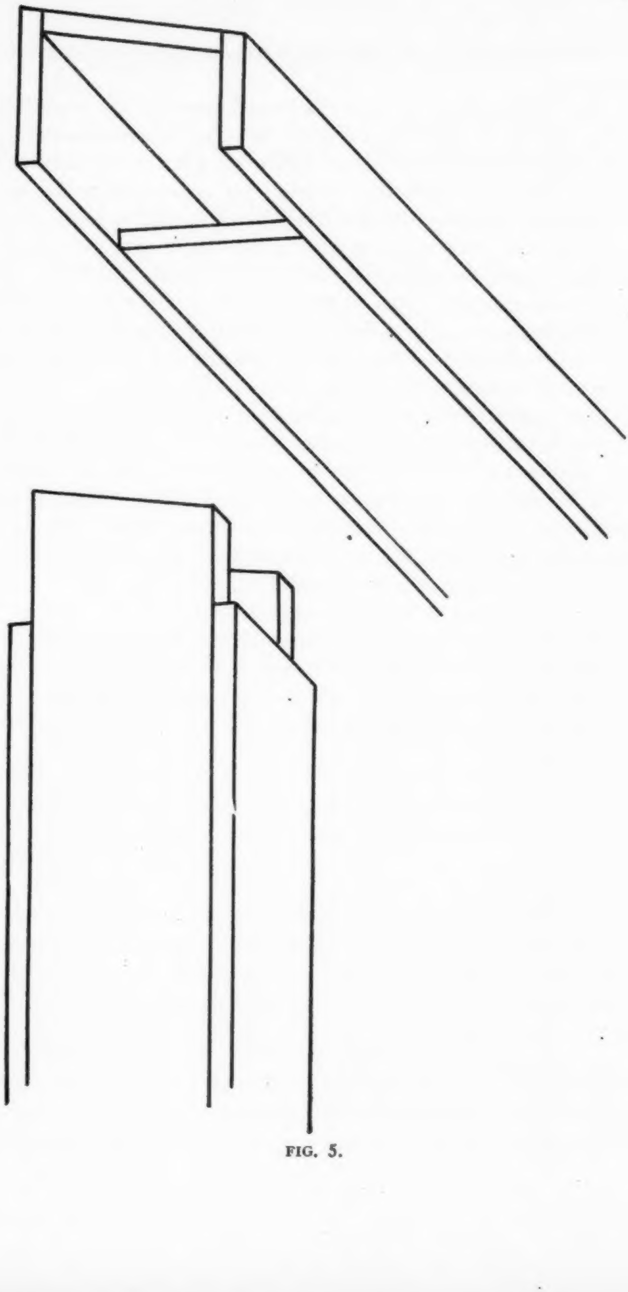


FIG. 5.

to synthetic atomic and molecular work on stable and unstable compounds.

The patternmaker is apt to be looked upon by the manufacturer as artistic—a kind of a luxury. But the patternmaker of the future must and is going to have a different place in the industrial arena. With a constructive training his opportunities for promotion never were brighter, for through specialization in the other departments the sources from whence the bigger men were drawn have been partially destroyed, and the employer will look more to the patternshop for this supply. Some of the patternmakers are alive to this fact and are preparing themselves for it, as is very evident from the number we see as foundry foremen, superintendents and incumbents of other responsible positions.

The manufacturer is giving the best indication of encouragement, he is taking him out of cellars and attics and providing him with comfortable quarters, he is organizing industrial schools for his benefit, he is saying to the patternmaker—"there is the foundation—build." Constructivity, when the seeds are properly planted, is both interesting and fascinating. It teaches resourcefulness and is a developer of originality. It attracts and it leads. It is a pleasurable means to a profitable end.

Should you find your pattern production lagging and are at a loss how to stimulate activity, before applying the megaphone method, thereby spreading a discordant feeling among the men, ascertain if a decided change cannot be made in the mode of "construction."

LIGHTING FIRES IN CUPOLAS.

By A. H. Stein, Brooklyn, N. Y.

It is a well-known fact that in lighting up the cupola with wood, a number of points have to be observed, otherwise an unevenly lighted and settled bed will result. As carelessness in this regard has caused many a poor heat in the foundry, attention was naturally drawn to the use of oil burners to light up the coke bed properly and without the use of wood. Years of experience have proved that absolutely uniform results under any weather or foundry conditions can be obtained by the use of a properly constructed oil burner.

Considering the steady increase in the purchase price of wood, the storing and handling is in itself a factor worth while considering. It is a common practice to leave the cupola work entirely in the hands of a melter, the foundry foreman being occupied with other seemingly more important work than overseeing the cupola. All is well until difficulties arise, and in nine cases out of ten all the melting troubles can be attributed to the bed of the cupola. It has been found that in many instances the coke bed did not kindle properly, leaving "*dead*" wood which will be consumed only when the melting is in progress, but surely causing an uneven settling of the coke and the following charges, and consequently variations in the temperature and quality of the molten iron will occur.

The Hauck Company were pioneers in developing the idea of lighting up the coke bed of the cupola, and as the result of much experimenting, perfected the necessary burners and apparatus to do this successfully. Whenever properly constructed burners are used and the few simple details, which consist merely in having a loose layer of coke directly over the sand bottom properly distributed, are observed, a quick and uniform lighting is obtained, especially if dry coke is used for at least the first twelve inches. It is immaterial whether the oil burner is applied through the breast opening or through a specially cut hole either under-

neath the slag hole or at some other convenient place. Naturally the burner flame should strike even with or slightly upward over the sand bottom and in such a way that it "passes" through the various channels all over the bottom.

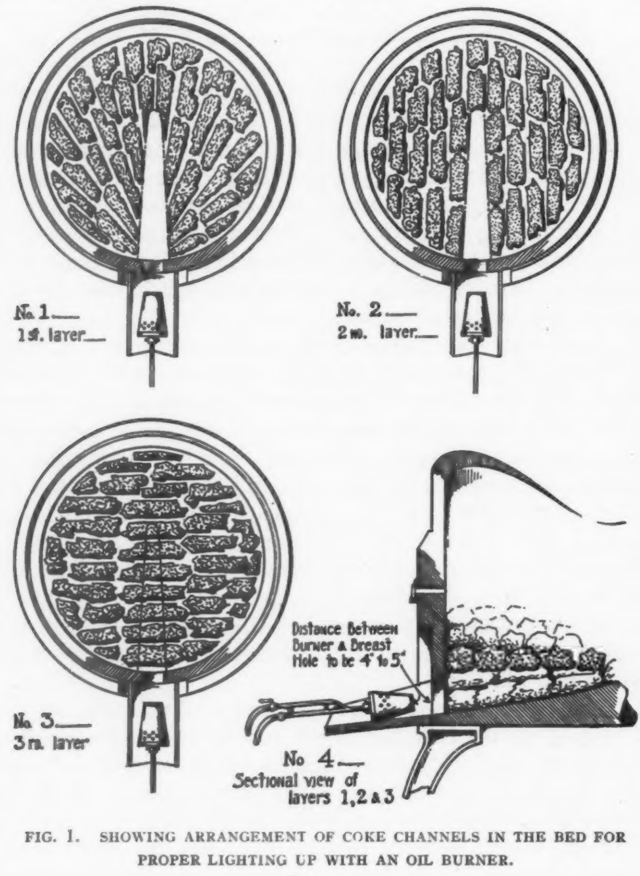


FIG. 1. SHOWING ARRANGEMENT OF COKE CHANNELS IN THE BED FOR PROPER LIGHTING UP WITH AN OIL BURNER.

Once the coke is ignited so far that dull red spots can be seen through the tuyeres, which takes, according to the conditions and the diameter, from ten to twenty minutes, the burner should

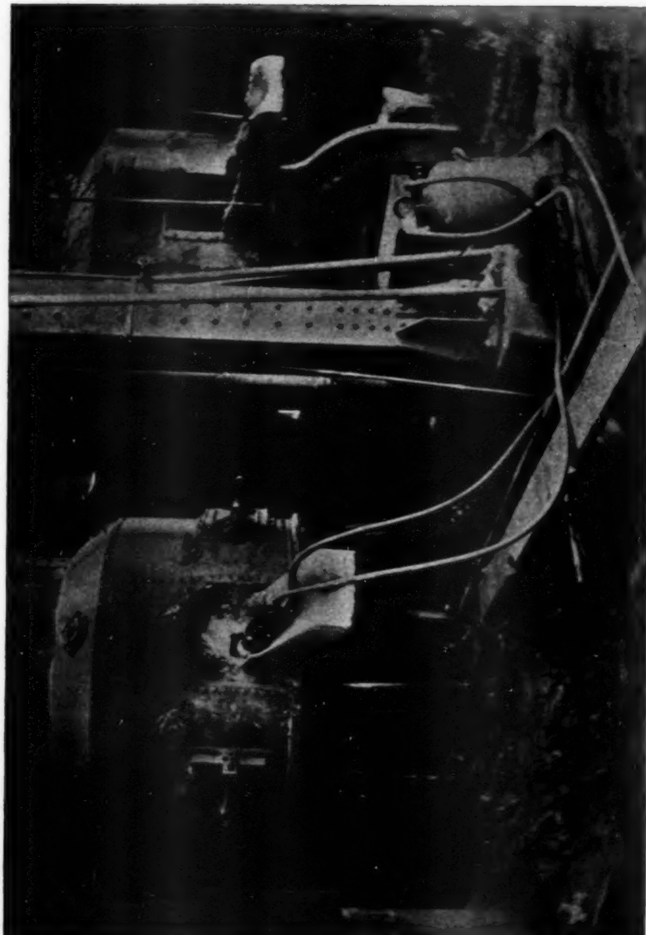


FIG. 2. SHOWING ARRANGEMENT OF BURNER TO START "LIGHTING UP".

be stopped, and the natural draft will do the rest. For the start about one half of the coke bed charge should be placed into the cupola, but always the larger pieces first. Pieces of coke about the size of an ordinary brick are most suitable for the first layer over the sand bottom. As soon as the red spots appear, the regular bed charge should be added with a small quantity of coke left over for leveling up. The opening which has been used for lighting can then be closed, and only the tuyeres which were previously closed (or partly closed) opened until the upper bed is burned suitably to receive the following iron and coke charges.

All this time the cupola and surroundings are free from smoke, and what is still more important to the foundryman, a solid uniformly lighted and uniformly settled coke bed is maintained. The daily bed charge should be "gauged" to be sure to always have the proper height of the bed, once this has been obtained by timing the first molten iron. Where the system of *weighing only* is in practice, it will be frequently found that a gauge is more reliable on account of the variations in the conditions of the coke.

From the point of view of what an oil burner should perform on a cupola, it is evident that, once the bed is charged and lighted properly, any reasons for disturbances in melting which may occur can easily be traced and remedied. It is also found that the first iron comes clean and hotter than with wood, owing to the absence of ashes. The white hot iron cools off in these until a height is obtained when the ashes float freely or are caught by the incoming blast through the tuyeres and blown upward.

As to the cost of lighting, it is found that up to 60 in. inside diameter of cupola, not more than from $\frac{3}{4}$ to 2 gallons of oil are required. Above 60 in. in diameter, in the proportion of about one gallon to the foot in diameter. Fuel oil or crude oil selling at from 2 to $4\frac{1}{2}$ cents per gallon, and kerosene from 5 to 9 cents per gallon in barrel lots according to locality, can be used. It becomes evident that the cost of labor besides the cost and storing of wood is far more than lighting with an oil flame. Many tests have been made with various constructed oil burners, whereby various results have been obtained, and it has been found that only an oil burner that is of the simplest construction and gives at all times a perfect combustion is of value. Where an inefficient oil burner termed "just as good" is used, not only more oil is consumed and much

FIG. 3. LADLE HEATING ARRANGEMENT IN CONNECTION WITH THE HAUCK BURNER.

time is wasted, but the results in every case will be unsatisfactory owing to the fact that the coke does not ignite as desired. The bed has to be exposed to the bottom draft longer than otherwise required, causing the coke to burn out and leaving considerable ash.

Oil burners which are used with fuel or crude oil can be operated with compressed air only. These burners have the advantage of instantaneous lighting and that some air can be driven into the cupola with the burner after the oil is turned off, causing a very rapid lighting of the bed charge.

Oil burners used with hand pump attached are to be used with kerosene (coal oil) only. The performance of both type of burners is practically the same, the difference lying in preheating the latter, which takes usually from two to four minutes, and that the cupola has to be left to ignite further by natural draft similar to the practice of lighting with wood. However, this is done with much less expense and in much less time.

The lifetime of a properly constructed oil burner has no limit, and if handled with care it lasts a lifetime. Besides the advantageous application of oil burners on cupolas, the same burners can be used for various other operations, such as drying and heating ladles. If properly arranged, any quantity of ladles can be dried (without an oven) and thereby eliminating smoke nuisance in the foundry. For skin drying or baking molds, preheating defective castings for "burning on", an oil burner which gives complete combustion is indispensable.

MECHANICAL SAND TEMPERING.

By V. E. Minich, New York City.

The shop conditions, product, equipment and materials, and number of men employed in the foundries of the members of this Association vary so widely, that a paper discussing the mechanical preparation of molding sand must necessarily deal with the subject in a very general way.

Only in recent years have the majority of foundrymen come to fully realize how greatly their production is affected by the care taken in tempering, or, to use the commonly accepted term, "cutting" their sand. Foundrymen have admittedly been negligent and, of course, their negligence has not been confined to sand preparation alone, but has extended, more or less, to every operation.

That there are still many foundrymen who do not appreciate the significance of modern machinery and improved foundry practice and its possible relation to their production and profit, is doubtless true, but it is no less true that an increasingly large number of foundrymen are wide awake, alert and ready to test any improvement in shop practice, or any mechanical device which gives fair promise of reducing hand labor, which is always at a premium when times are good, or of increasing quantity and improving quality of production and reducing loss. And it is to these conventions and the various foundrymen's associations no less than the untiring work of the various equipment manufacturers that the credit is due.

Those of you who have attended these conventions for several years past and who have carefully examined the equipment exhibited in conjunction therewith, cannot fail to have noted the remarkable increase in variety and improvement in the quality of equipment shown, as well as the deep interest felt by the foundrymen in mechanical improvements, as evidenced by their painstaking examination, investigation and frequent adoption of the same.

As relates to the preparation of sand: While French, German and other foreign foundrymen seem to have long realized the value of perfectly cut sand, it is certain that the majority of our foundrymen have been slow to recognize or accept its importance. They have freely admitted that better cut sand produces better castings with smaller loss, but, having made the admission, they have continued to permit the use of poorly cut sand in their foundries, apparently losing sight of its bearing on their production and profit. This is principally due, no doubt, to two reasons: (1) Intangible profit; (2) The labor problem.

As to profit. No tangible, definite figures can be given in advance of an installation showing just what saving can be made. Indeed it is often impossible to give exact figures even after such a system has been put in service, but it is significant that once an efficient, mechanical system for preparing sand, or, indeed, for performing any other shop function, is adopted it is rarely discontinued.

As to labor. The great difficulty of getting laborers to cut sand right is known to everyone, and if one will take a shovel and thoroughly cut a few sand heaps himself, one is likely to feel some sympathy for the laborer, who, having nothing more encouraging than a laborer's wage to hold him steady, becomes discouraged and spends a night over a can of beer, leaving an uncut sand heap to face the molder upon his arrival on the job five minutes before the whistle. Under these circumstances, whether or not the molder cuts it himself and works that day, is likely to be determined by the urgency of "Little Jimmy's" need for a pair of shoes, or perhaps it may depend upon who "rules the roost" at home. To avoid the annoyance and loss from such occurrences some foundrymen require their molders to cut their own sand regularly. This can only result in a waste of the molder's skill, energy and productive capacity and a direct and material reduction of profit, which could be wholly avoided by the use of sand cutting machinery, if backed by efficient management and active supervision.

As is doubtless true of foundry machinery for every purpose, one of the most serious difficulties encountered in the practical adoption of sand cutting machinery is prejudice. Prejudice, perhaps, on the part of the foreman, or possibly even on the part

of the superintendent, but more frequently on the part of some individual molder.

Every employer of any considerable number of molders has had sorrowful experience in his foundry due to some self-appointed leader of thought among his molders, some vain fellow of quick wit, glib tongue and loud voice, who does not hesitate to sacrifice the interests of his employer and his fellows to gratify some prejudice, or whim, or even to show his influence. It has been the experience of every one who has attempted to bring about an improvement in foundry methods, to find the most obvious and easily accomplished improvement opposed and often defeated by the attitude of just one such man, who, strangely enough, has been known to influence the judgment of foundry foreman, superintendent and manager more than the silent approval of all the other men, and doubtless before mechanical sand cutting is universally adopted, to the great relief and profit of the foundryman and the advantage of every molder, many defeats will be suffered from this cause alone. Incredible as it may seem, experience has shown instances where one individual has been able to successfully oppose machinery which would have afforded mutual profit to foundryman and molder and daily relief to both, whose only apparent motive was an anarchistic opposition to machinery of every type and for whatever purpose. The danger of permitting such influence to remain unchecked is too apparent to require comment. In this connection we have observed with surprise, and some regret, that foreign labor, under efficient supervision, has often shown more appreciation of labor saving machinery than many of our supposedly enlightened American mechanics and laborers, though this remark is by no means intended to apply to American molders and foundry labor in general.

This subject of the right attitude of mind toward all mechanical devices of merit is of utmost importance to you foundrymen whose future progress and profit will be largely determined by your success in meeting and combating such prejudice. If you are to progress, prejudice must step aside. The individual obstructionist must be eliminated. In no other department of industry have the neglected possibilities for profit been so long unrecognized and progress so long delayed as in the foundry, and you cannot hope to bring your foundries to the high state of efficiency that has

been attained in other industrial lines unless the awakening of the past few years is followed by openminded willingness to set aside all prejudice and test all improvements upon the basis of merit.

During the past few years various kinds of mechanical apparatus for conveying, elevating, screening, tempering or otherwise preparing and mixing molding sand have been developed. But owing to the fact that the majority of this equipment is of special design, built and installed in especially constructed buildings to meet individual conditions, from the smallest operation to the most complete conveyor systems, as for instance: The Westinghouse Company at East Pittsburgh, Pa.; Crane Company at Chicago, Ill.; Kelley & Jones, Greensburg, Pa.; American Brake Shoe and Foundry Company at Chicago; General Fire Extinguisher Company at Providence, R. I.: Central Foundry Company at Holt, Ala., and others, this paper cannot deal with such installations. Each of these elaborate plants could be described only in a special paper and would have to be personally inspected for a perfect understanding. The equipment which has been standardized sufficiently to meet the general needs of the majority and is being manufactured commercially is small in variety and confined to a very few manfacturers, and for obvious reasons a paper of the scope of this one is necessarily limited to a general description of such apparatus.

Until within less than a decade there were very few foundries where any attempt was made to temper sand mechanically, and it is, perhaps, not too much to say that where the earlier attempts were made the results obtained were usually rather indifferent.

The devices now available for performing part or all of the functions of sand preparation may be divided into five different classes, as follows:

1. Completely mechanical conveyor and tempering systems.
2. Sand conveyor systems.
3. Self-propelled sand cutting machines.
4. Stationary mixing machines.
5. Portable riddling machines.

Inasmuch as this paper deals, more particularly, as previously mentioned, with sand tempering, we shall make no mention of the last two classes further than to point out that each occupies a valuable place: The stationary mixing machines, better known as

"batch mixers," in blending materials and preparing core and facing sands and the portable riddles in cleaning sand heaps of scrap.

As to sand tempering: It will be understood that any system to be completely successful and to afford results which justify its use must insure a condition of sand at least equal to the best possible hand-cut sand; indeed, unless the sand is uniformly put in better condition, mechanical tempering loses its best claim for consideration.

The completely mechanical conveyor and tempering systems are by the nature of things limited in their application to the very large foundries which specialize in the production of uniform articles of commerce, such as Kelley & Jones Company, Greensburg, Pa., and Central Foundry Company, Holt, Ala.

The same is largely true of the sand conveyor systems. A few examples of which are those in use by:

The General Electric Company, Pittsfield, Mass.

The Worthington Pump Company, Harrison, N. J.

Crane & Co., Chicago, Ill.

The General Fire Extinguisher Company, Auburn, R. I.

In each of these plants a continuous melting system is employed; the molding is done on an upper floor where the cupola is located. The molds are shaken out over gratings, the sand drops on the lower floor where it is prepared and shoveled into sand conveyors, whence it is returned to the molder's bench or machine, no attempt being made to cut the sand mechanically at the first three named, while at the General Fire Extinguisher Company's plant a self-propelled sand cutting machine is employed to cut the sand. Had this machine been available and provided for in the plans when the foundry was designed it would have been possible to both cut and deliver the sand to the conveyors by the sand cutting machine, thus eliminating much hand labor.

The self-propelled power driven machines are usually applied without any change in shop construction or material change in shop practice, except as to cleanliness and order which in themselves result in increased efficiency. They are applicable to the smallest as well as the largest foundries and to a widely varying range of shop conditions, due to the fact that they are driven under their own power. Like an automobile, they run on the floors where the sand has been shaken out and the sand is cut by the machine and

left right where it is to be used, identically as in shovel cutting for floor molding. For stationary bench or squeezer work the sand is cut and piled in the stall by the machine, saving all carrying of molds, wheeling, or shoveling back.

It is not necessary to describe the details of design of any of the systems in use, but it may be worth while to point out some of the problems to be met by the foundryman contemplating the use of any mechanical tempering device.

One of the first questions to be considered is cost. There are many prosperous concerns who would be glad to use every kind of modern machinery that could be profitably applied to their conditions, but quite often a going, growing business has two places for every dollar available, in which case the first cost is a most serious consideration. This is doubly true if to the cost of equipment must be added the expense of remodeling or rebuilding. On the other hand it is usually possible to secure reasonable accommodation from one's bank for the purchase of machinery which will yield a profit, or better still, manufacturers of equipment will often sell their machinery upon long time terms so that the saving effected by the machinery provides the funds to pay for it; or it is even possible to rent machinery and secure the benefit of the resulting increased efficiency without any investment—the saving effected, of course, paying the rental and leaving a margin of profit.

The most serious difficulty encountered by the completely mechanical conveyor systems in which the finished molds are conveyed, poured, shaken out and the sand wet, mixed and returned at once to the molder, is the elimination of the time necessary to free the sand of gases, and the combination of air, moisture and heat to perform the chemistry of soil dissolution. That peculiar plastic quality desired in molding sand is obtained in just the same way that nature, assisted by the hoe or plow, prepares the soil which beds around and nourishes the growing roots of the vine. Water alone impoverishes, heat alone burns and moving air dries the soil. A considerable length of time must elapse between wet down and cut, otherwise the bond will be weakened and the sand will not mold so well nor give as good a result as though allowed to lie for from two to four hours before being cut.

It is of interest to know that one large engineering concern

in this country is considering the use of a high elevator for the purpose of raising the sand and dropping it over baffling bars in order that the air may penetrate to every particle and hasten the cooling process. But it is, in my judgment, very doubtful whether or not the sand thus rapidly cooled will give as good results as though allowed to lie and undergo the more gradual action of combined water, heat and air. In fact at least one case is known where, in connection with a mechanical conveyor and tempering system, it was found necessary to deposit the sand into a large bin carrying a sufficient supply to permit all sand to lie twenty-four hours before using. With the introduction of these storage bins, the serious trouble which had previously been experienced with the sand, at once disappeared.

Another difficulty in completely mechanical systems, even on duplicate work, is to secure a uniform amount of moisture; particularly as the humidity varies from day to day or even as it rises and falls during a single day. It is usually conceded by engineers working on these processes that complete mechanical tempering will prove only moderately satisfactory and will apply only to a limited class of articles, such as those requiring no particular finish or quality, but merely weight, thus rendering the condition of the sand comparatively unimportant. Castings made by these processes are usually either used as taken from the sand with mere cleaning or so considerably machined or coated as to render a smooth surface of slight value.

The type of device best suited to each foundryman's requirements is, of course, a question for determination by each foundryman after careful investigation of the various systems and consideration of their applicability to his conditions, but I would urge upon each foundryman the importance of investigating this subject because of its bearing upon his production and labor conditions. Economical production is your most vital consideration. Everything hinges upon volume and cost of production, and it has been repeatedly demonstrated that the use of sand preparing machinery has increased volume and reduced cost. But labor conditions are only second in importance. Each year it becomes more difficult to get competent molders and laborers in sufficient numbers to meet the most urgent requirements, and when business conditions are good and orders most plentiful, competent labor

not only commands a premium, but is often actually not obtainable. So prominent and able a foundry superintendent as Mr. Wiltshire, Foundry Superintendent of the General Electric Company, Schenectady, N. Y., recently remarked that "the foundryman who is able to maintain present labor costs and secure competent labor equal to his requirements, must be recognized as an able, successful man." There is a quite evident and growing distaste for the molder's trade among the hardy class of Americans who have in the past composed the flower of our journeymen mechanics. This is to be regretted, because no one can doubt that America's position in the world's commerce is largely due to the character of her mechanics. Manufacturers will do well to relieve their mechanics, so far as possible, of all objectionable duties which are not essentially a mechanic's work, such as sand-cutting, and do such work with machinery, or, if necessary, with common labor, concentrating their mechanics' time and effort on work that requires skill, thus increasing production and at the same time making the work more attractive.

The help afforded by the use of sand preparing machinery is obvious. There are hundreds of foundrymen to-day who are doing this work with hand labor, because they believe their conditions are not suited to the use of machinery. In the majority of cases this is not true, and an investigation of the different systems and consultation and advice from men experienced with the various systems, would show some one or more of them profitably applicable. And especially should the foundryman who is planning new buildings or additions consult with the representatives of the firms making the different systems, because experience has repeatedly shown that timely consultation as to lay-out, etc., would have saved money and resulted in higher efficiency.

Any manufacturer who has the confidence in his device which begets confidence will be glad to inspect your foundry and offer you a proposal to install his equipment on approval. When the other fellow is willing to invest his money and let you be the judge of his claim that his equipment will make you money, it's pretty safe to be "from Missouri" and let him "show you."

But I cannot refrain from sounding one note of warning before closing: No machine for any purpose will accomplish satisfactory results unless it is backed by competent and intelli-

gent interest and determined support on the part of the management. No machine can furnish the backbone needed to establish system and co-operation among employees, which is necessary to the successful and profitable operation of any machine, and I should strongly urge any manager who doubts his ability to enforce discipline among his men and command loyal support from his superintendent and foreman against the adoption of any machinery either for sand preparation or for any other purpose, because almost invariably lukewarm support of machinery only results in dissatisfaction to foundryman and disappointment, if not loss, to the manufacturer. Machinery supported by brains, energy and determination is invaluable, but not otherwise. And especially should the manager who permits either himself or his superintendent or foreman to regard the work of supervision in establishing a system as "too much bother" rather than a duty and source of profit, for which he is paid, leave modern machinery alone. Consistent support, covering a reasonable period of time, will almost invariably demonstrate suitable machinery to be profitable after which it becomes a part of the shop system and requires no unusual attention, but it is certain that a machine seldom reaches the successful stage in any foundry without such consistent support. My advice is: Don't put in any machine until you have made up your mind that the machine is a good thing. Then, having decided, don't lie back and leave it to the manufacturer to work out his own salvation; back him at every step with determined support and your joint efforts will soon work out a system which will prove its merit in the results accomplished.

Mechanical sand tempering is now an established practice in perhaps 150 foundries and while this is a small percentage of the whole it is worthy of note that those now using mechanical devices for this work, either in part or whole, include such progressive and well-known concerns as: American Radiator Company, Brown & Sharpe Manufacturing Company, General Fire Extinguisher Company, International Harvester Company, Niagara Radiator and Boiler Company, Oliver Chilled Plow Works, Pratt & Letchworth Company, Remington Typewriter Works, Singer Manufacturing Company, Standard Sanitary Manufacturing Company, Yale & Towne Manufacturing Company.

Among those who are about to install mechanical tem-

pering machines are: General Electric Company, Vulcan Iron Works, North & Judd Manufacturing Company, Landers, Frary & Clark, Johnston Harvester Company, Wilmington Malleable Iron Company, Whitin Machine Works, Buffalo Forge Company, Frontier Iron Works.

Wherever it has been possible to secure the interest and co-operation of manager, superintendent, foreman and molder, the improvement in physical conditions following the installation of mechanical sand preparing machinery has resulted in an increase of production, improvement in quality and general gain in efficiency amounting to a splendid showing of profit, and if peace of mind and freedom from anxiety concerning that most fruitful source of trouble, sand cutting, is taken into account it has surely paid large dividends in the conservation of nervous energy which is so valuable in securing results and which always commands high prices.

SOME THOUGHTS ON THE PROBLEM OF THE FOUNDRY.

BY C. F. DUDLEY, NORTH TONAWANDA, N. Y.

It is pretty generally agreed that some way must be devised to turn out a greater supply of trained molders for the future, and that quickly. In a few thousand shops there are turned out annually one or two molders apiece. Many of the recruits never advance beyond the stage of handymen, and either remain valuable to the foundry in which they were raised, or else travel about and give their subsequent employers some experience. The others who have really something in them get, or ought to get, the "Wanderlust" and go out to see the foundry world, work in the best shops they can find, and gradually perfect themselves in the art of molding. These men become highly prized acquisitions, but in the winnowing from the chaff but a few hundreds remain from the thousands originally graduated into industrial life.

A few of our larger establishments have recognized this situation and go about the training of young men into molders systematically. Foundry trade schools and other courses of instruction will add their quota, and so it will be seen that at least a small beginning has been made in the way of grappling with the situation.

A large shop which trains men likes to keep them at the jobs which will give the quickest cash returns. Hence good men will not remain. The small shops cannot afford high wages for the average young molder, hence they lose him also. Very few molders or foremen will give a boy more than a bare chance to learn his trade.

American men who have pondered deeply over these things, are beginning to realize that much of the labor involved in training apprentices in the foundry in order to furnish a future stock of molders, should be done by the common school. The American boy is a born mechanic, but he seldom has his gifts in that direction properly developed.

Germany and France have long ago mastered this phase of the educational problem. Perhaps our strenuous life—not shared to a great extent in Europe—has prevented us from recognizing this as much as we ought. Mr. Andrew Carnegie rightly said that only the progressive individual of a family emigrated to this country. The others stayed at home. Yet these "stay-at-homes," properly trained, turn out most excellent work. Indeed what profits it to turn out a hundred molds here when forty per cent of them are not perfect, and when sixty per cent could be made perfect in the same time by those men over there who know how.

Why cannot we be thorough also here. Why not face the music and quietly admit that the average American casting, though of good quality, would not prove acceptable in Germany, for instance, owing to surface blemishes. Were we to be in competition in the interior of Europe, we would soon learn this.

It would be idle to moralize on the subject, without offering some possible solution for the problem of the future molder. In the molder's family circle, with his children growing up, each boy by his environment early forms some idea of the trade or profession he would like to follow. More usually he follows the life-work of his father. In every calling there are many ways in which the son comes into touch with the father in his vocation. The real solution then lies with the public school. After the ordinary studies have been passed—to give the boy a general necessary education, studies should be taken up bearing upon his future vocation, and directly profitable to him. In the first place he must be adapted to the work he intends to follow up. If we were better fitted for the work we follow up, the Nation would be further ahead. But in the school, as the boys get to an age when they must choose, the teachers should be better qualified to judge whether the vocation chosen is likely to be the right one. The teachers should be able to teach the arts sufficiently well so that the boy can also know whether he is on the right track. With the art of molding there should be combined all those collateral studies, such as chemistry, mechanics, etc., which make the molder better qualified to grapple with the niceties of his work when he has acquired the manual dexterity he needs in the shops he works in after leaving school.

COMPRESSED AIR—A FOUNDRY NECESSITY.

By Arthur F. Murray, East Cambridge, Mass.

1. To say that no foundry should be without an adequate supply of compressed air is almost as trite as to say that no steam power plant should be without steam. But, in spite of the many advantages that the user of pneumatic appliances has over the foundryman who is without them, many foundries throughout the country are without any supply of compressed air and a larger number make less use of it than they should.

2. It is not the purpose of this paper to present a scientific treatise on compressed air or a mass of figures as to costs of operation and resultant savings. These are so dependent on individual conditions that figures drawn from general statements would be of little value to you. I shall merely attempt to outline the uses to which compressed air is put by the wide-awake foundryman, leaving you to select such of the applications for your own use as best suit your purposes. In addition a few remarks will be made as to compressors, piping and installation.

3. It may be well to list the more important uses for compressed air in the foundry, starting with the handling and mixing of materials and proceeding through the core and molding shops to the cleaning room and shipping floor.

4. Applications of Compressed Air:

Handling Materials.

Air hoists.
Pneumatic elevators.
Pneumatic cupola charging machines.
Fuel oil systems.

Core Shop.

Core carriage hauling devices.
Core sand preparation (pneumatic riddles).
Core-making machines—jolt ram type.
Core-making machines—roll-over types.

Molding Floor.

Molding machines:

Plain jolt or jarring type.

Combination jarring and squeezing types.

Combination jolt ram and pattern drawing types.

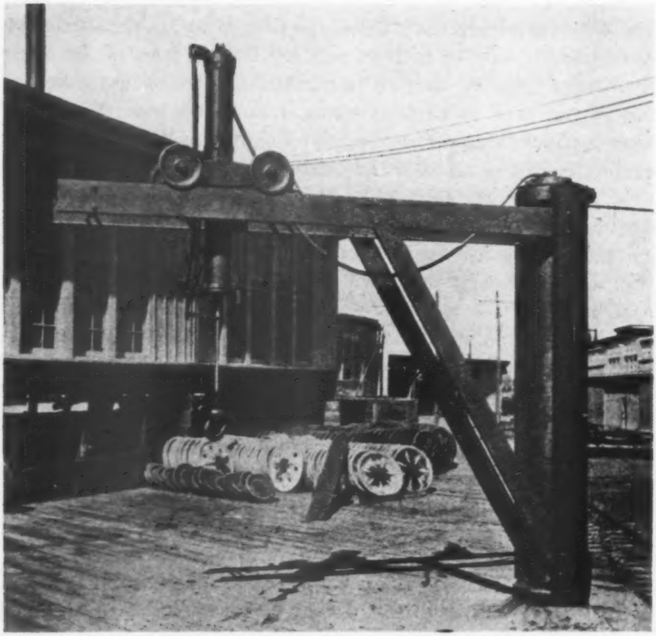


FIG. 1.—DIRECT LEFT AIR HOIST MOUNTED ON JIB CRANE.

Plain vibrator types, power squeeze types.

Power squeeze, power draft types.

Power squeeze, power roll-over, power draft types.

Power sucker types with vibrator.

Pneumatic rammers.
Pneumatic molding sand sifters or riddles.
Blow guns.
Spraying devices.

Cleaning Room.

Pneumatic chippers.

FIG. 2.—PLATFORM TYPE PNEUMATIC ELEVATOR.

Sand blasts—high or low pressure.
Sand blast tumbling barrels.

Handling Materials.

5. Fig. 1 shows a common type of direct air hoist mounted on a jib crane in the receiving yard. These hoists are frequently

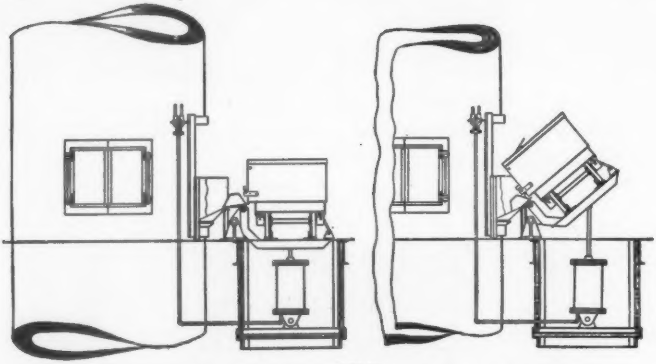


FIG. 3.—PNEUMATIC CUPOLA CHARGING MACHINE—DUMPING ONLY.

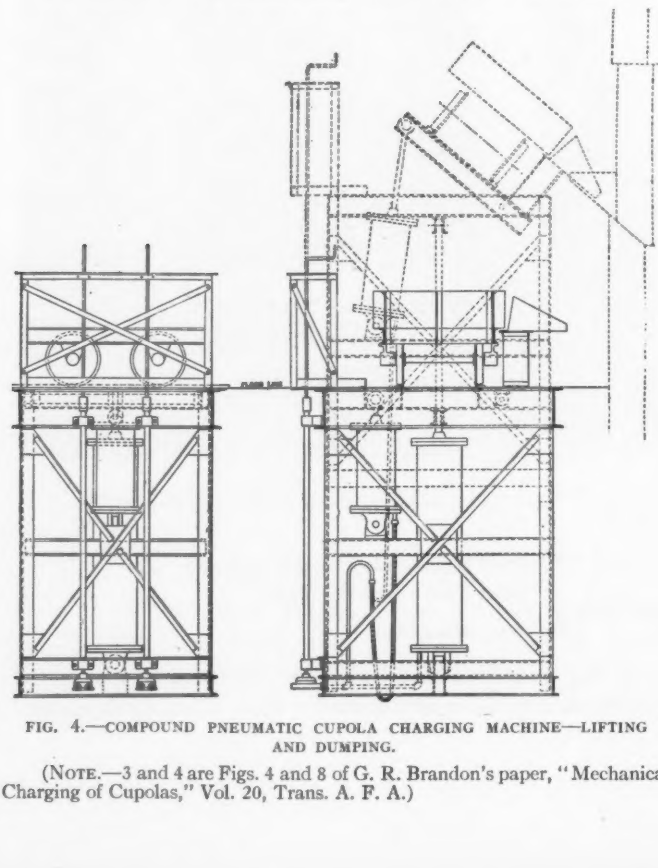


FIG. 4.—COMPOUND PNEUMATIC CUPOLA CHARGING MACHINE—LIFTING AND DUMPING.

(NOTE.—3 and 4 are Figs. 4 and 8 of G. R. Brandon's paper, "Mechanical Charging of Cupolas," Vol. 20, Trans. A. F. A.)

mounted on traveling bridges, the hose being supported by a special trolley or a reel. Where the lift is more than four to

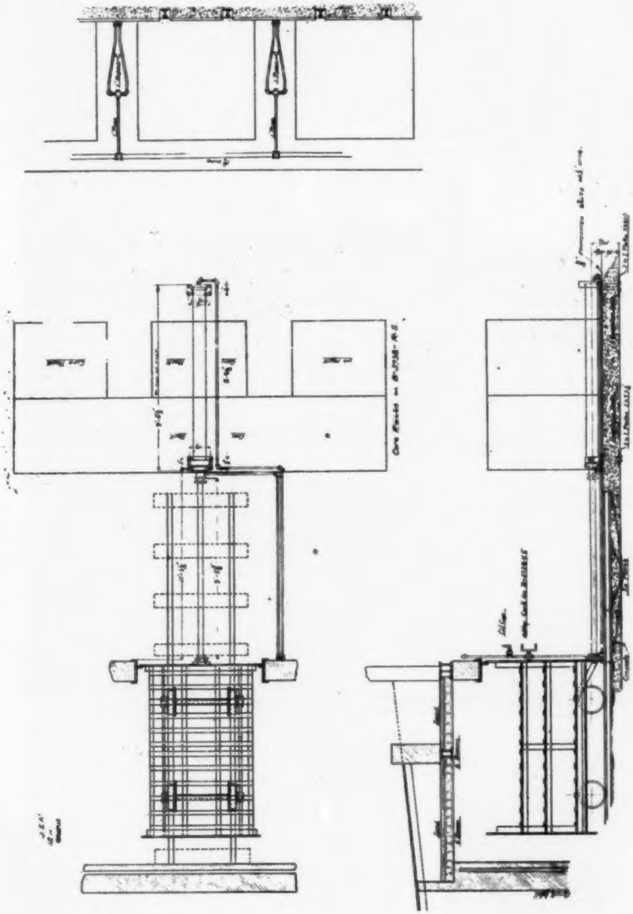


FIG. 5.—COMPRESSED AIR CAR HAULING AND DOOR OPENING DEVICE FOR CORE OVENS.

six feet geared air motors are frequently used to operate a chain or wire rope hoist.

6. Fig. 2 shows a type of air elevator frequently used instead

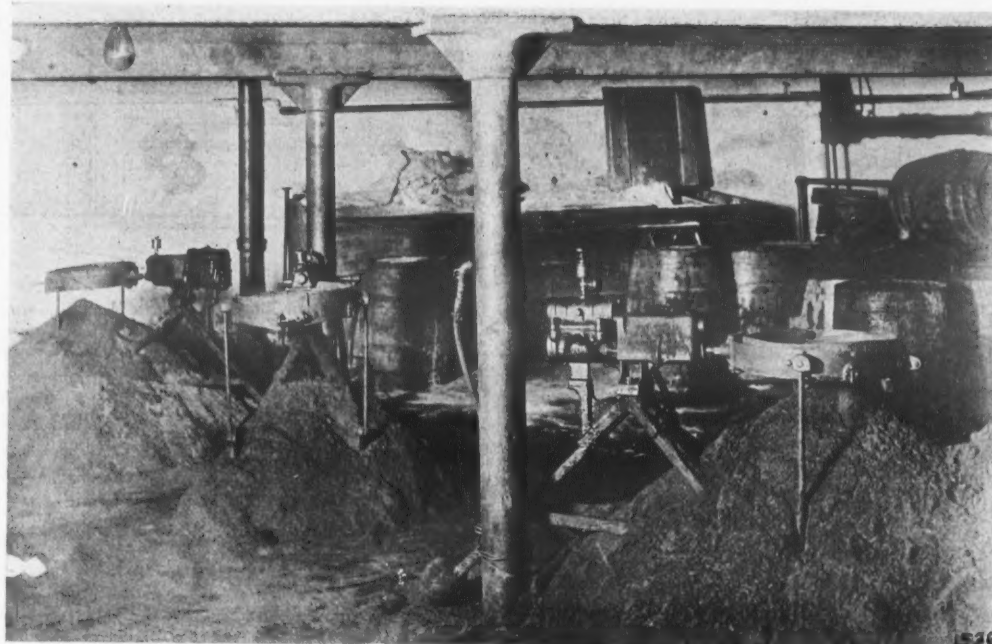


FIG. 6.—PREPARING CORE SAND WITH THE USE OF PNEUMATIC RIDDLES.

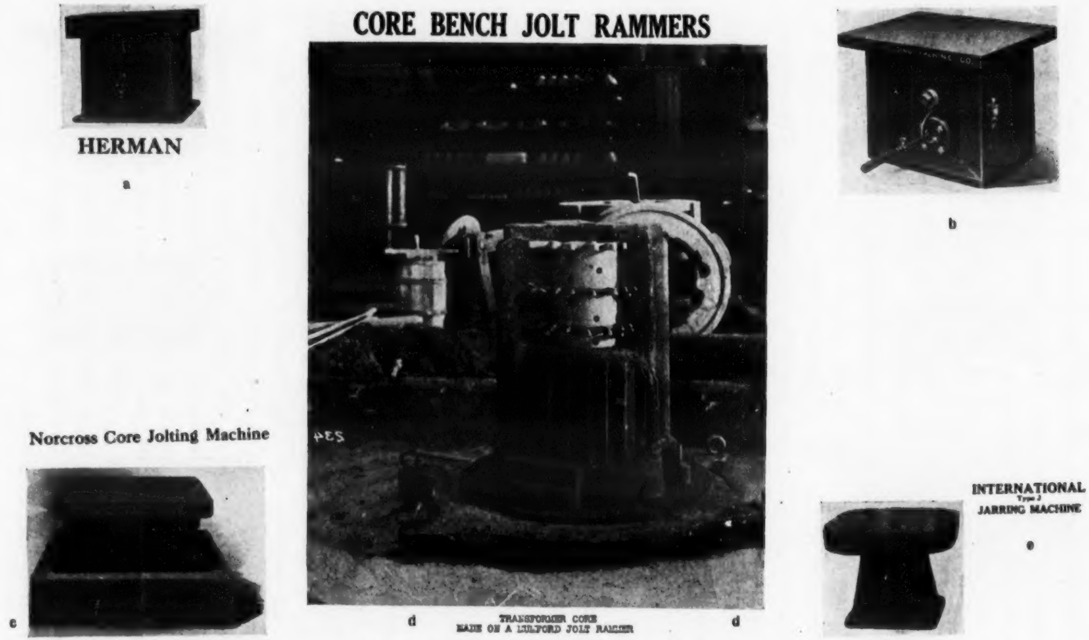


FIG. 7.—TYPES OF CORE JOLTING MACHINES.
(*a*) Herman. (*b*) Mumford. (*c*) Norcross. (*d*) International. (*e*) Transformer Core made on Mumford Jolt Rammer.

of hydraulic elevators for sand pits or other places where hydraulic elevators would mean long lines of large piping, expensive pump installations or trouble from freezing. It is simple, cheap and effective, although not to be recommended for the continuous service of the cupola stage. Where the lift is long, indirect air elevators, similar to the indirect hydraulic elevators used in office buildings are frequently employed.

7. A special form of pneumatic elevator is the cupola charging machine, Fig. 3. This shows a type for use where the charge requires no lifting. Fig. 4 shows a compound type in which the charge is both lifted and tipped by the machine. These devices are rapidly coming into favor.

8. A great many foundries use fuel oil for skin drying, melting furnaces, core ovens, etc. The air displacement system is a simple means of transporting this from the place of storage to the place of use. In this system air is not applied directly to the storage tanks but alternately to two small pressure tanks which receive their supply of oil by gravity from the main storage tanks. Simple cross-over valves are used and changed over once or twice a day, usually by hand, but sometimes automatically.

9. *The Core Room.*—The handling of core carriages has always been a troublesome job. Fig. 5 shows a simple compressed air haulage device which is self-explanatory.

10. The mixing of core sand by compressed air is frequently done by means of the pneumatic riddle shown in Fig. 6.

11. The core room is often a neglected part of an otherwise up-to-date plant. Therefore opportunities for savings are usually good. If core costs can be sufficiently reduced, the entire molding practice may be radically changed, coring taking the place of difficult pockets, loose part work or multiple part flasks. Fig. 7 shows a number of "core jolt" machines. They make the manager smile and the pattern-maker "holler." For success on the core jolt machines, boxes must be substantially built or they will be knocked to pieces. But the cost of a well built core box is little more than that of a poorly built one, and the use of core jolt machines will reduce most core costs twenty-five to fifty per cent. In the center of Fig. 7 is shown a difficult transformer core made on a Mumford jolt rammer.

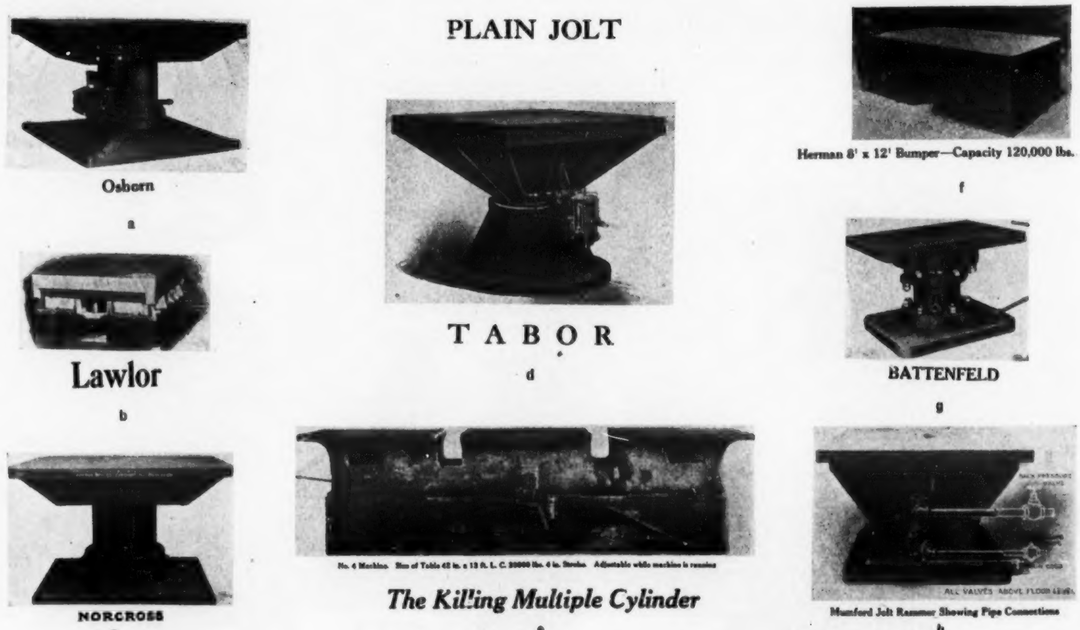


FIG. 8.—TYPES OF PLAIN JOLT RAMMING OR JARRING MACHINE.
(*a*) Osborn. (*b*) Lawlor. (*c*) Norcross. (*d*) Tabor. (*e*) Killing. (*f*) Herman. (*g*) Battenfeld. (*h*) Mumford.

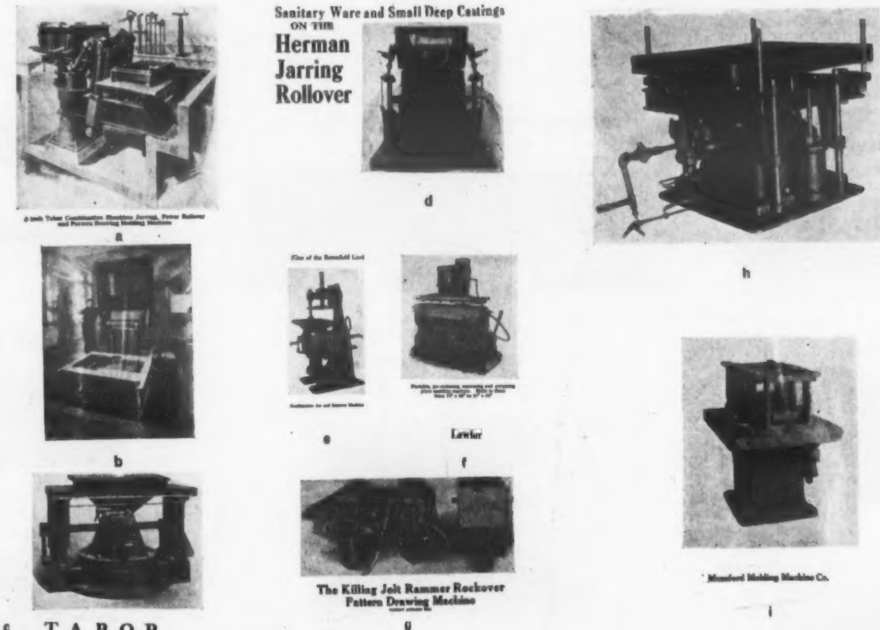


FIG. 9.—TYPES OF JARRING MACHINES WITH SPECIAL ATTACHMENTS.

(*a*, *b*) Tabor shockless jarring and roll-over machine. (*c*) Tabor jarring machine with pattern draft attachment. (*d*) Herman jarring roll-over machine. (*e*) Battenfeld jarring and squeezing machine. (*f*) Lawlor portable jolt ramming, squeezing and stripping plate machine. (*g*) Killing portable jolt ramming rock-over. (*h*) Mumford jolt rammer with outside pattern draft apparatus. (Old style Mumford gear shown.) (*i*) Mumford jolt rammer with central draft stripping plate apparatus.

FIG 10.—16 IN. 72 BY 72 IN. PLAIN JOLT RAMMER AS INSTALLED IN FOUNDRY OF BLAKE & KNOWLES STEAM PUMP WORKS, EAST CAMBRIDGE, MASS.

12. Various other types of air-operated core machines are now being manufactured, among them the Gow power ramming roll-over machine which was described in a paper by E. A. Coleman at last year's convention. This uses the squeeze principle for ramming and is not as hard on core boxes as the jarring machine.

FIG. 11.—6 BY 9 FT. 20-TON JOLT RAMMING MACHINE IN FOUNDRY OF LAIDLAW-DUNN-GORDON CO., CINCINNATI, OHIO.

13. *Molding Machines, Jarring Types.*—One of the most remarkable changes in foundry practice during the past five years has been caused by the general adoption of the "jarring machine," "jolt rammer," "bumper" or "bouncer," as it is variously termed by makers and users. No other single type of molding machine

is applicable to as wide a range of work, or requires as little special pattern and flask work. The most remarkable thing about it all is that the jarring machine was invented in 1869 and was forty years in coming into its own.

14. Fig. 8 shows eight of the prominent makes of jarring

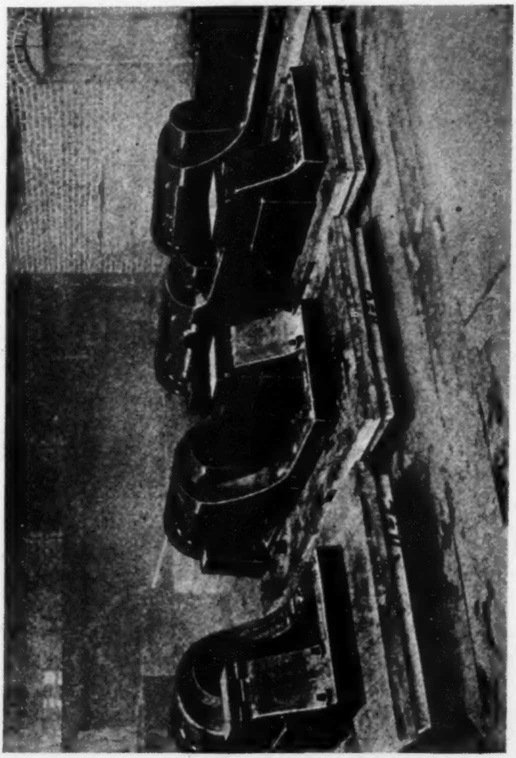


FIG. 12.—ENGINE FRAME PATTERNS MOUNTED FOR JOLT RAMMING MACHINE.

machine. Fig. 9 shows the application of special devices for rolling over the mold or drawing the pattern. These are built as combined jar and squeeze, combined jar and roll-over with pattern draft, combined jar and stripping plate, etc. A number of these types have been the subject of special papers before the Associa-

FIG. 13.—SMALL JARRING MACHINES, INSTALLED ABOVE THE FLOOR LEVEL.

FIG. 14.—BRYAN "SUCKER" PATTERN DRAWING DEVICE WITH VIBRATOR ATTACHMENT.

tion. They are of considerable value where extreme accuracy is required and where there is much duplicate work. Given adequate crane service, the plain jarring machine will be found more satis-

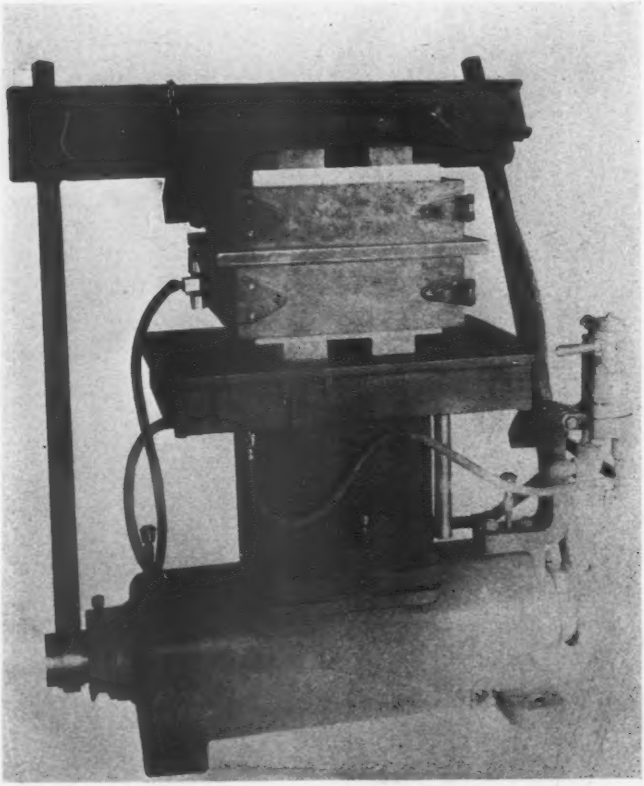


FIG. 15.—PLAIN POWER SQUEEZER.

factory for the average jobbing foundry than these specialized machines. It is the same problem that the machinist faces when deciding on turret machines or engine lathes.

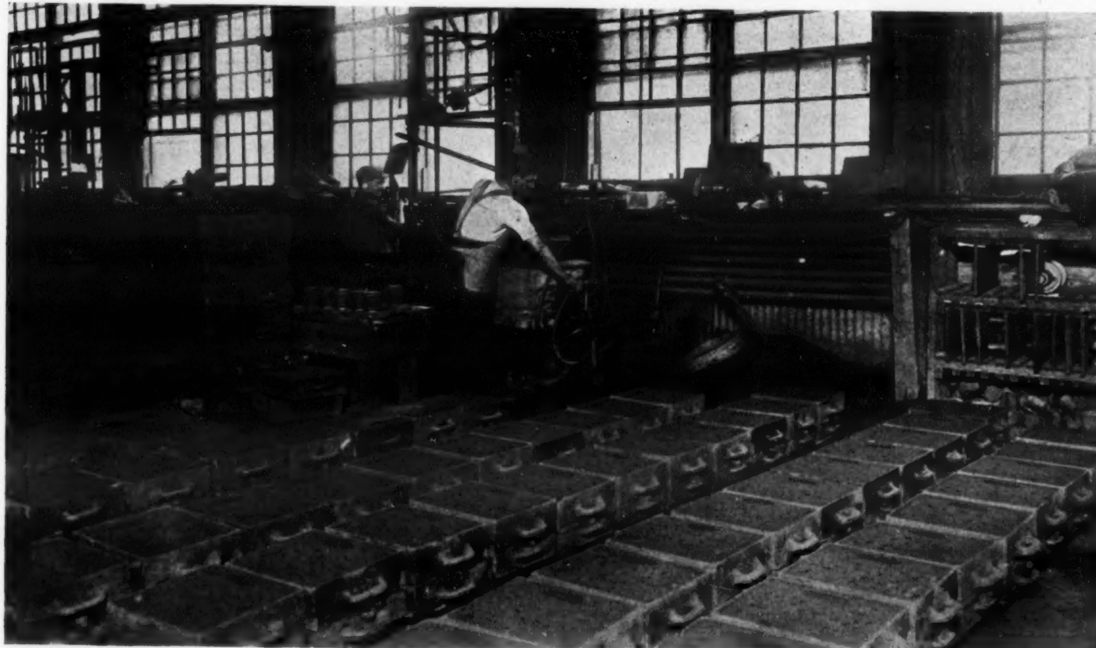


FIG. 16.—SPLIT PATTERN TYPE POWER SQUEEZER. ("Sucker" machine arranged for hand ramming in background.)

15. I shall now show a few views of jarring machines in operation. Fig. 10 shows a 16 in. 72 by 72 in. machine in the Blake & Knowles foundry and a small corner of its molding floor. Things to be noted are the electric jib crane and the air hoist installed especially for setting cores and finishing molds rammed on the jarring machine. The control valve and air pressure gauge

FIG. 17.—POWER TURN OVER POWER DRAFT MOLDING MACHINE.

will be noted alongside the wall. The hoists are in addition to the two overhead traveling cranes on the 200-ft. crane runaway.

16. One of the most essential requirements for profitable operation of jarring machines is efficient crane service. Nothing will "show up" the crane service like the presence of a good sized jarring machine on the hand molding floor. Inefficient crane service in a hand molding foundry of course means idle time for

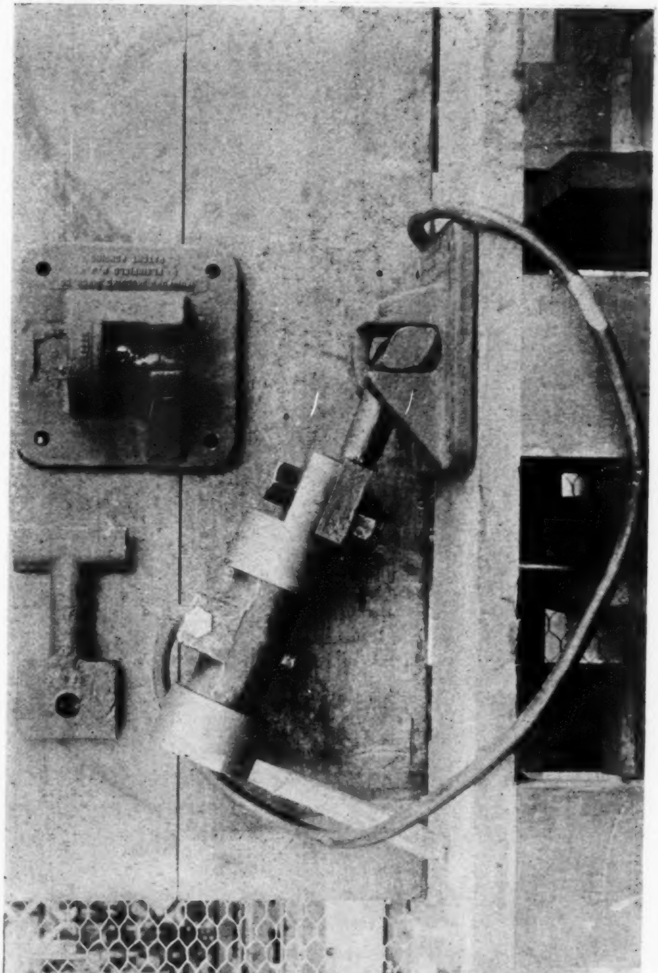


FIG. 18.—VIBRATOR ATTACHMENT FOR PATTERN BOARDS.

FIG. 19.—PNEUMATIC RAMMER FINISHING OFF JAR-RAMMED COPE.

the molder, but he will usually not make much of a row about that. When the jarring machine comes in, the foreman and manager are watching it and delays caused by the crane are quickly noted. In properly operating the jarring machine, molds are set up on

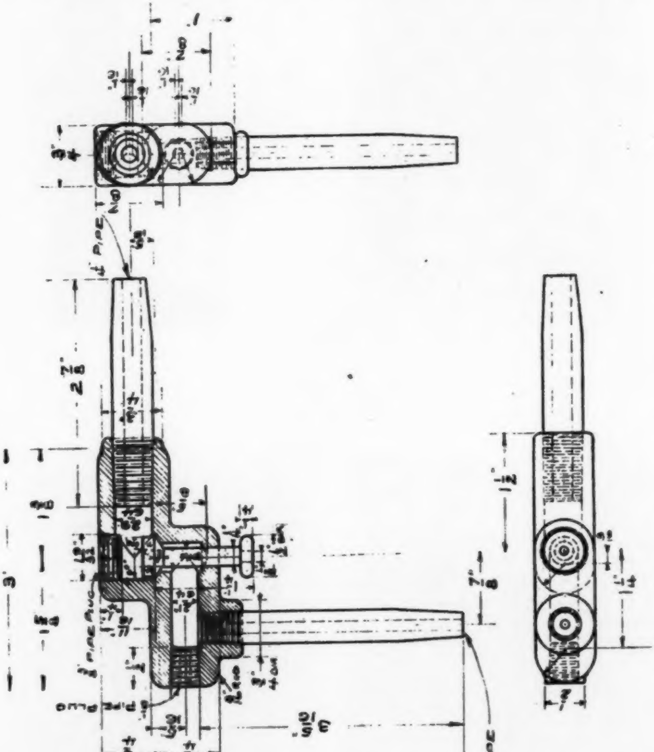
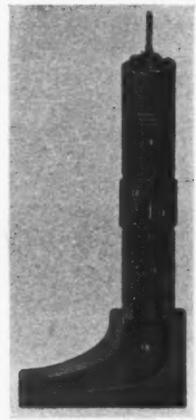


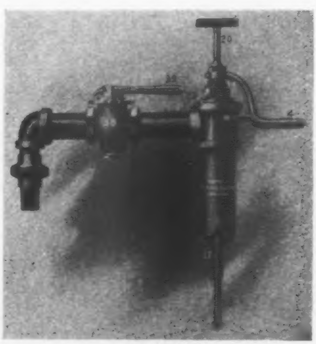
FIG. 20.—AIR GUN FOR BLOWING OUT MOLDS.

the floor, clamped, picked up by the crane, carried to the machine and rammed, picked up again and turned over, and then carried to the finishing floor by the crane. In connection with the machine just illustrated I have found it profitable to install five-ton independent high speed auxiliary hoists on each of the two sixty-foot

SAND-BLAST BULLETIN
[illegible]



SAND-BLAST BULLETIN
[illegible]



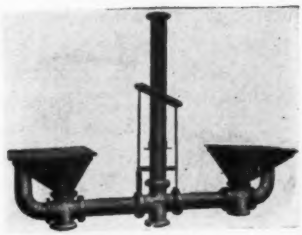
SAND-BLAST BULLETIN
[illegible]

"PANGBORN"
[illegible]
SAND-BLAST SYSTEM
Type "C"

"PANGBORN" IDEAL SAND DRYER

[illegible]

FIG. 21.—PANGBORN HIGH PRESSURE SAND BLAST.



SUCTION HOPPERS

904

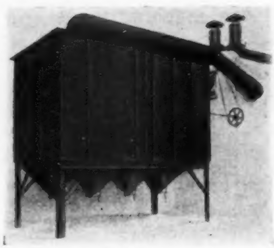


FIG. 912

DRY PROCESS DUST COLLECTOR

PAXSON-WARREN (P) SAND BLAST MACHINERY

PORTABLE SAND BLAST MACHINE WITH WATER TRAP

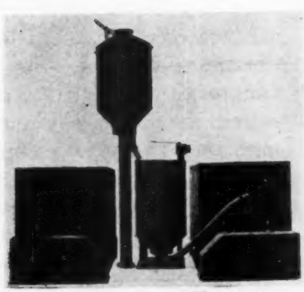


FIG. 902

SAND BLAST TUMBLING BARRELS WITH SUCTION ELEVATOR

END VIEW

FIG. 22.—PAXON-WARREN SAND BLAST EQUIPMENT.

traveling cranes in this foundry, as well as to install a two-ton electric jib crane and an eight-inch air hoist.

17. Fig. 11 shows part of the jarring machine installation of the Laidlaw-Dunn-Gordon Co. In this picture a 6 by 9 ft. twenty-ton machine is shown. In the background is shown a flask being lowered on to the pattern board. Fig. 12 shows the method of arranging patterns for Corliss engine and compressor frames for the jarring machine in the same works. The pictures are taken from an article in the August, 1910, *Foundry*.

18. Fig. 13 shows two jarring machine floors for small work which is usually done on roll-over or stripping plate machines. The work on these floors is done by one molder without helper. The photograph was taken at noon and shows a morning's work. Each of the small floors is served by its own one or two-ton electric hoist and traveler. The machines are shown in the background. They are set with tables about twenty inches above the floor to enable the molder to stand up at his work. Eight machines of this type have replaced twenty plain stripping plate and roll-over machines in this foundry.

19. *Other Types of Molding Machines.*—The jarring machine, though covering a wide range of work, is not a universal panacea for high costs and poor castings. For novelty work the plain hand squeezer with vibrator attachment is widely used. For this same class of work the ramming is sometimes done by hand or on a plain squeezer, and the pattern drawn by a "sucker" Fig. 14, with vibrator attachment. Fig. 15 shows a plain power squeezer with vibrator attached to the pattern plate. Fig. 16 shows a split pattern type of power squeezer, which is built by several companies and is very successful on small work. Fig. 17 shows a power turn-over, power draft machine or "roll-over," machine. This type is built with variations of detail by several companies. Fig. 18 shows the application of a vibrator to pattern boards. This is successfully used for drawing patterns rammed on the jolt rammer.

It is not my purpose to show views of all the molding machines on the market, but merely to point out that there is a wide variety of machines from which to choose, most of them designed for "hooking on to the compressor." The very fact that there are so many types of air-operated molding machines only

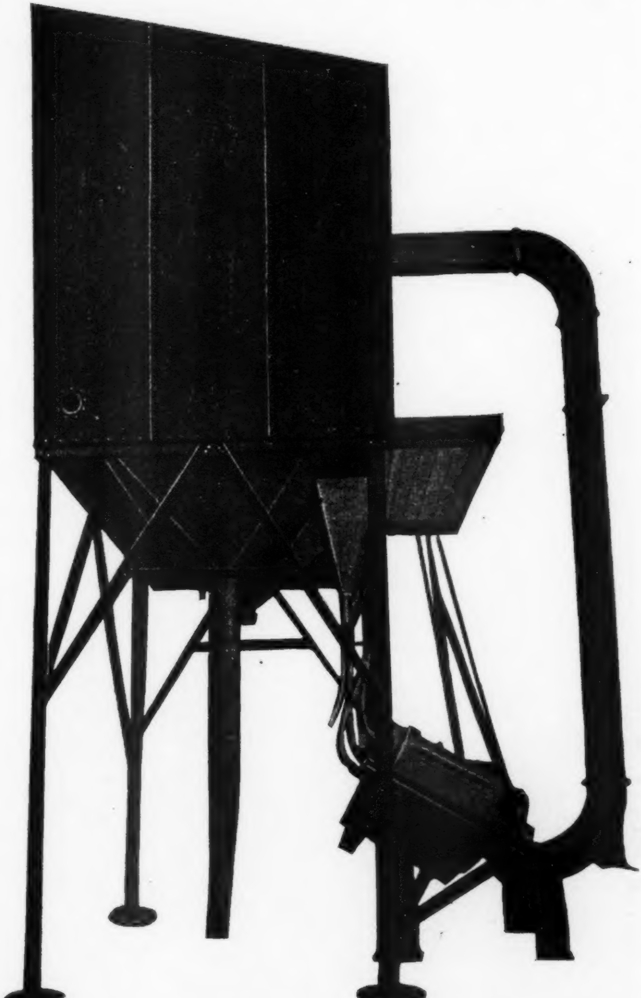


FIG. 23.—SLY SAND-BLAST TUMBLING BARREL WITH DUST ARRESTER AND SUCTION ELEVATOR.

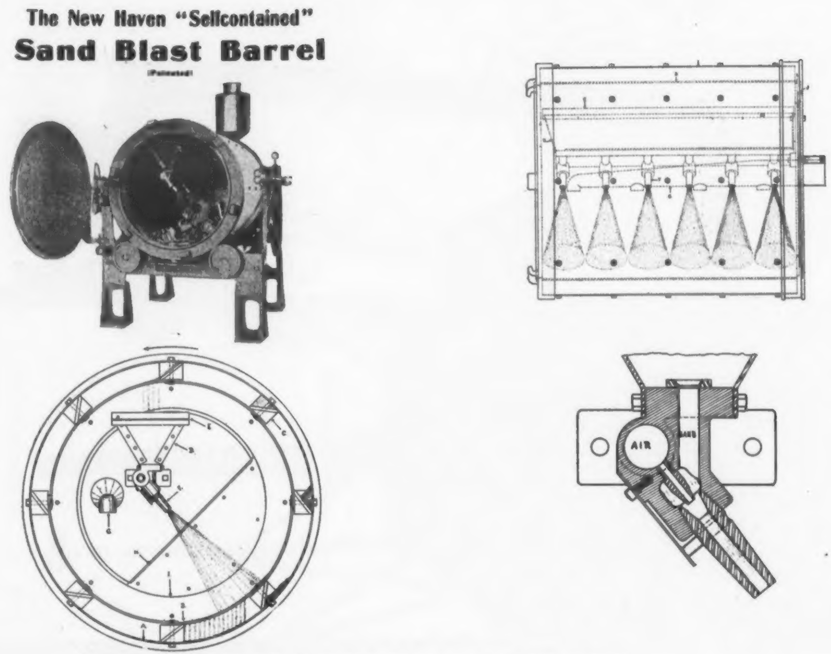


FIG. 24.—NEW HAVEN SAND-BLAST BARREL.

(*a*) Barrel open. (*b*) Side view detail. (*c*) Front view detail. (*d*) Sand nozzle detail.

FIG. 25.—PNEUMATIC CHIPPING HAMMERS CHIPPING CYLINDER CASTINGS.

e1 .phasizes the previous statement that air is to the foundry what steam is to the power plant.

20. *Pneumatic Rammers and Blow Guns.*—While speaking of molding machines I must not forget two verv useful auxiliaries—the sand rammer and the blow gun. Fig. .9 shows a pneumatic rammer finishing off the top of a cope rammed on the jarring machine. It is also a labor saver on ordinary floor work. Fig. 20 shows a simple form of blow gun for cleaning out dirt from patterns and molds.

21. We have now made the mold, set the cores and poured the casting, using air hoists and elevators for handling material, pneumatic riddles for preparing sand, oil and air fired ovens to bake the cores, pneumatic core machines to make the cores, and pneumatic molding machines. There now remains but to clean the casting, snag it and ship it, clean up the gangway and temper the sand for the next day's heat.

22. *Sand Blasts.*—The subject of sand blasts is so broad that it can only be treated adequately in a separate paper. A number of types of sand blast apparatus will be mentioned to indicate how compressed air has been applied to the cleaning of castings. Fig. 21 shows the Pangborn high pressure sand blast and two details of the sand valves. It also shows a simple sand dryer. Sand used in any machine must be dry to prevent clogging of the nozzle. Where a recovery system is used, chilled steel shot or angular steel grit is a better abrasive to use than sand. Fig. 22 shows the Paxon-Warren sand blast machine, and an arrangement of same with two sand blast barrels and a suction elevator. It also shows a type of dry dust arrester.

23. *Sand Blast Tumbling Barrels.*—For cleaning small castings that are not fragile, there is no better method than the sand blast tumbling barrel. These are manufactured in a number of types. One has already been shown in Fig. 22. There are a number of machines built on the principle of a rotating barrel with one or both heads stationary. A nozzle or nozzles from a regular sand blast machine is inserted through openings in these heads. Most of these machines operate on the low pressure system. Some return the sand to the machine by a suction system and some by gravity. They all operate inside of an outer case closed by sliding, swinging or rolling door, and connected to an exhaust system

FIG. 26.—DEANE PNEUMATIC SAND RIDDLE RECTANGULAR TYPE.

FIG. 27.—DEANE PNEUMATIC SAND RIDDLE ROUND TYPE.

Fig. 23 shows a modification of the arrangement as built by Sly of Cleveland. The big tank-like affair is the dust arrester and sand-tank. The mill is tipped at an angle and sand and dust are withdrawn through one trunion, as in the well-known Sly exhaust mill. The cleansed sand returns by gravity to the nozzles located in the stationary head of the mill. Fig. 24 shows the New Haven sand blast barrel which is self-contained. The heads are stationary and the shell is double. Fastened to the head is a sand hopper provided with a number of air nozzles. The action is quite plainly seen in the line drawing. The sand or shot falls to the bottom

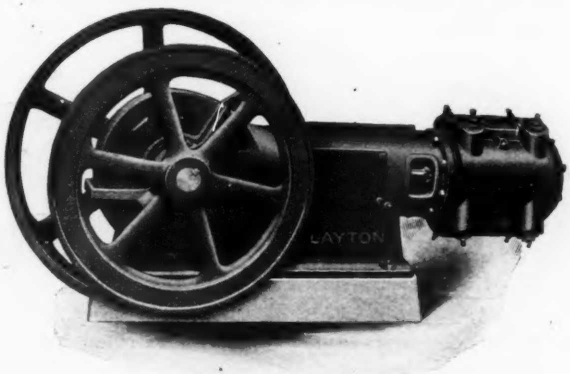


FIG. 28.—ENCLOSED FRAME SPLASH LUBRICATED POWER DRIVEN AIR COMPRESSOR—SIZE 10 BY 10.

and is picked up by the vanes fastened to the outer shell and deposited in the hopper for further use. This machine is a medium pressure machine, usually operating at 60 lbs. pressure.

24. An efficient sand blast or sand blast tumbler, either of the high or low pressure type, will remove sand and scale, and leave castings better-looking than either a plain rumbling machine or the emery brick, wire brush and pickling tank. Castings have been cleaned and their cores cut out in less than an hour each with the sand blast that could not be cleaned by hand in two days. I know of one place where a sand blast tumbling barrel replaced a pickling tank with the result that shipments could be made at

least one day earlier than before. The product required galvanizing and was sand-blasted and put in the galvanizing bath the day after it was cast instead of losing a day in the pickling vat.

25. *Chipping Hammers.*—The casting now being clean the fins, etc., are chipped off with a pneumatic chipping hammer—Fig. 25. One man chipping with a chipping hammer is as good as two or three with hand chisel and sledge, and the work looks better and smoother. A skilled chipper will quickly remove fins or bunches so that they appear scarcely to have existed.

26. *Sand Riddles.*—We now have only to cut the sand for the next day's work to bring us back to our starting point. Fig. 26 shows a large sized Deane pneumatic sand riddle cutting sand

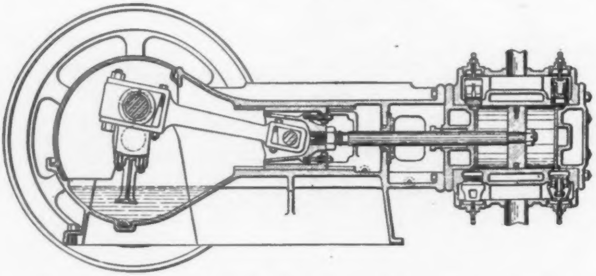


FIG. 29.—SECTION OF 10 BY 10 ENCLOSED FRAME POWER DRIVEN AIR COMPRESSOR.

for the main floor or cleaning up the gangway. This machine will handle all the sand that four or five laborers can shovel into it and makes quick work of this job. Fig. 27 shows a smaller machine of the round riddle type, located between two split pattern machines in a machine foundry. The sand for these two floors is cut by the molders themselves.

27. *Care of Pneumatic Tools.*—A few words about the care and upkeep of pneumatic tools. Before attaching a tool, blow out the air line and squirt oil into the valve. Do not use an air hammer all day long without oiling it. If the hammer has not been used for some time, squirt a little kerosene or benzine into it, connect up the hose, operate the machine for a few strokes, then disconnect and squirt a light machine oil, or sewing machine oil, into the hammer. Several of the large oil refiners now supply a special

pneumatic tool oil which should be used if possible. New hammers are always furnished with a gauze strainer. This should be kept in good condition as rubber particles and rust from hose and pipes are liable to clog valve passages if allowed to get into hammers. It is a good plan to suspend the hammers over night in a bath of kerosene to clean them out and to prevent rusting from moisture in the air. They must then surely be lubricated before using, as the kerosene leaves them dry. There are a number of makes of automatic oilers on the market to be attached to the air line a few feet from the hammer. If none of these is used the hammer should be oiled several times a day. Chisels should be kept in

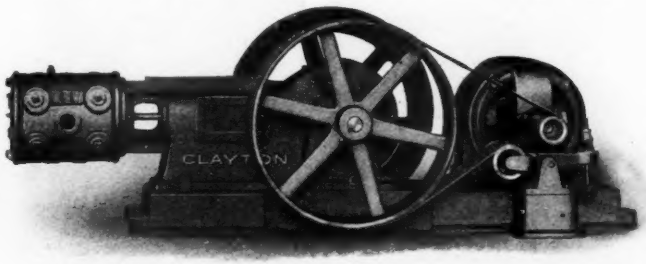


FIG. 30.—8 BY 6 IN. ELECTRIC DRIVEN ENCLOSED FRAME AIR COMPRESSOR—CLOSE BELTED TYPE.

shape and in general the hammer should be treated as if it were a piece of machinery rather than a piece of scrap iron.

28. *Pipe Lines.*—Piping should be as direct as possible with no undrained pockets or loops where moisture can accumulate and where freezing can occur in cold weather. Separators should be installed at low points on the line. These may be either the ordinary type similar to steam separators or may be air receivers. It is a good plan to locate a steel receiver of 25 to 50 cu. ft. capacity at points where there is a large fluctuation in compressed air demands. This combines the action of separator and equalizer, although it will not sustain the service if the compressor shuts down. Fittings should be of the "long turn" type and all shut-off valves of the gate type. All shut-off cocks on taps should be

of heavy pattern and good quality. The piping should be installed with care to insure a tight line and well supported so that the joints can not shake loose. A single ¼-in. orifice will deliver 21.2 cu. ft. of free air per minute at 80 lbs. pressure and the importance of preventing leakage is therefore readily seen. Hose should be heavy and preferably armored. Quick acting couplings should be supplied at both ends to prevent the reprehensible practice of twisting it up before screwing it into a tool connection.

29. *After-Coolers and Reheaters.*—After-coolers and reheaters

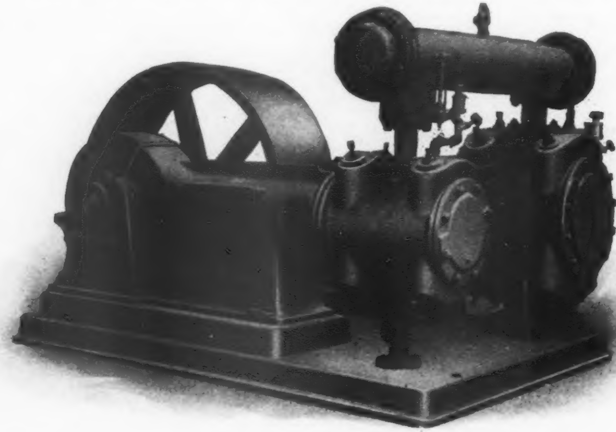


FIG. 31.—16 BY 10 BY 10 DUPLEX TWO-STAGE ENCLOSED FRAME AIR COMPRESSOR—POPPET VALVES ON BOTH CYLINDERS.

are usually unnecessary with foundry outfits, but where there is a plentiful supply of cooling water the use of a properly proportioned after-cooler will remove nearly all the moisture from the air before discharging the air to the pipe line.

30. *The Compressor.*—The average jobbing foundry requires a compressor of 300 to 500 cu. ft. per minute displacement. Large foundries may use up to 1,500 or 2,500 cu. ft. Novelty foundries frequently require small machines of 50 to 100 cu. ft. displacement. In selecting a foundry compressor, price should not be considered so much as service. The foundry compressor should be as nearly

dirt-proof and fool-proof as possible. Machines that would give perfect satisfaction when operated in connection with a power plant and in charge of skilled engineers frequently go all to pieces when installed in a foundry where skilled mechanics are not available, and where dirt and dust abound. These remarks refer not so much to the large foundry which maintains a good sized power plant either for itself or jointly with other departments of the works, as to the independent jobbing foundry which produces such a large percentage of our total foundry product. Fig.

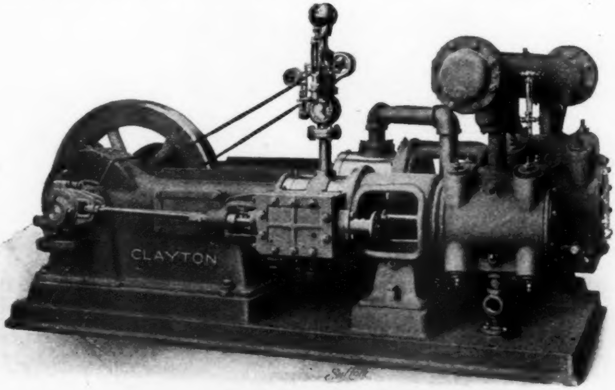


FIG. 32.—10 IN. AND 15 BY 16 IN. AND 10 BY 10 IN. CROSS COMPOUND STEAM DRIVEN ENCLOSED FRAME TWO-STAGE AIR COMPRESSOR.
(Mechanically moved inlet valves on low pressure cylinder.)

28 shows a type of machine which has been developed by a number of makers particularly for foundry service. It is the enclosed frame, splash lubricated type. The illustration shows a 10 by 10 belt driven machine built by the Clayton Air Compressor Works. Fig. 29 shows a cross section of this type and illustrates the dirt-proof features and the self-lubrication of the running gear by the splash system. Fig. 30 shows a common application of close belted electric drive to this type of machine.

31. *Two-Stage Compressors.*—Fig. 31 shows a 16 by 10 by 10 duplex two-stage compressor with heavy belt wheel for connection to electric motor. Best practice demands pressure of 80 to 100 lbs.

per sq. in. for the service lines of the foundry. Where the machine is to be motor driven with purchased power, the lower power consumption of the "two-stage" machine will soon make enough difference in the power bill to pay for the extra cost. Of course the economy is not affected by the fact that the power is purchased, but the results are more effectively brought to the attention. The two-stage machine will run cooler, and show a higher volumetric efficiency, *i. e.*, ratio of piston displacement to actual

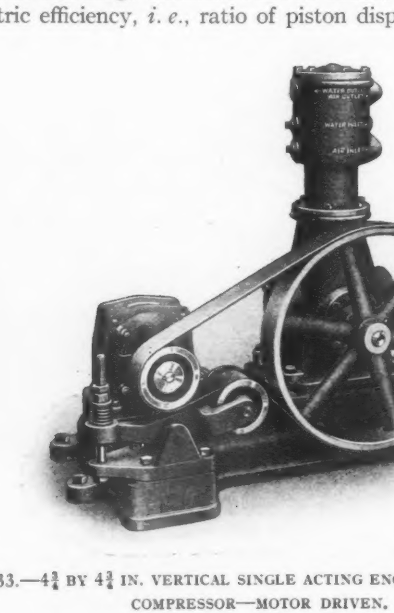


FIG. 33.—$4\frac{3}{4}$ BY $4\frac{3}{4}$ IN. VERTICAL SINGLE ACTING ENCLOSED FRAME AIR COMPRESSOR—MOTOR DRIVEN.

cubic foot equivalent free air delivered. It will usually be found profitable at 80 to 100 lbs. air pressure where a displacement of 300 cu. ft. per minute or over is required, whether the machine is steam or power driven. Fig. 32 shows a steam driven machine of the same size as Fig. 31. This is provided with cross compound steam cylinders and mechanically moved inlet valves on the low pressure cylinder.

32. *Small Compressors.*—The novelty foundry desiring to operate a few vibrator or squeezer machines has until recently

found difficulty in obtaining a satisfactory compressor. The advent of the automobile has brought forth a number of machines for garage service in pumping up automobile tires. Some of these machines are admirably suited to novelty foundry work. Fig. 33 shows a Clayton garage compressor close belted to electric motor, which has been applied to this service in a number of cases. Fig. 34 shows a larger machine of the same type in a triplex pattern. In addition to being used as compressors this type can be used as vacuum pumps. One of them is being used in the Blake-Knowles

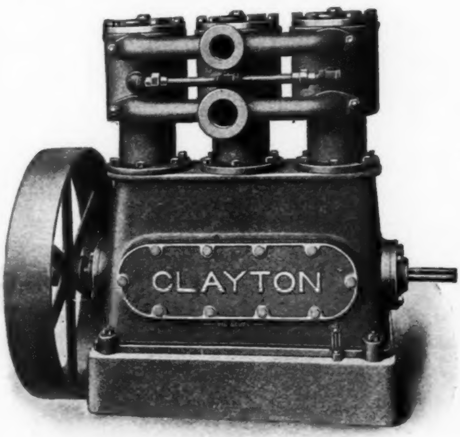


FIG. 34.—$4\frac{3}{4}$ BY $4\frac{3}{4}$ IN. TRIPLEX VERTICAL SINGLE ACTING ENCLOSED FRAME AIR COMPRESSOR, BELT DRIVEN.

foundry to operate a row of Bryant suction or "sucker" molding machines.

33. In discussing compressed air in the foundry one could easily digress in many directions, for compressed air is so thoroughly applied in the up-to-date foundry that a discussion of its use is a discussion of modern foundry practice. It has been my intention simply to set you thinking of places where compressed air would save money in your foundry and to discussing the statements made, whether you agree with them or not. If I have done this the purpose of this paper will have been accomplished.

ECONOMICAL CLEANING OF CASTINGS BY SAND BLAST.

By B. H. Reddy, Cleveland, Ohio.

In the operation of foundries wherein are made castings of iron or steel, there is much to occupy the time of the manager. Notwithstanding the many things which occur from time to time, one thing in particular, like the oft-mentioned Ghost of Banquo, is ever present. This is the problem of how to clean castings satisfactorily and economically.

Many things have been tried with more or less success—mostly less—until at the present time the sand blast equipment is the most economical method of satisfactorily cleaning castings for many purposes.

With its improvement and development the sand blast has become more and more widely known for the above mentioned service. Already for some lines of work the "sand blast finish" is demanded. This is especially true of the automobile and hardware trades, where the finer grades of castings are used.

There are a variety of machines and devices on the market to-day which possess more or less merit and which have been designed to suit the varying conditions and requirements of different kinds of work. Several forms of these machines will be designed later.

The sand blast in its simplest form consists essentially of a receptacle for the abrasive medium, means for conveying this to the nozzle, and the nozzle itself.

Abrasive Material.

There are a number of materials which may be used for the abrasive: Steel shot, crushed steel, or angular grit, and sand of various kinds being used for this purpose, the latter being the most commonly employed. While the advocates of steel shot claim that much can be said in favor of its use, the principal

claims are absence of dust; as the only dust made is from the castings themselves; and low cost, it being claimed that twenty-five tons of castings can be cleaned with a loss of steel shot amounting to fifty cents. Opponents claim that the rounded surface of the shot presents no cutting edges, and that with the re-use of angular steel, in a short time it also becomes rounded, so that it is virtually "shot." Where the surfaces of the castings are merely to be freed from sand, scale, etc., the use of steel will undoubtedly be satisfactory; but when the surfaces of the castings after cleaning are to be coated by some means, its use frequently becomes very unsatisfactory, to say the least.

While the surfaces of castings cleaned with steel may be entirely free from sand and scale, they appear as if finished or coated with stove polish or graphite, and do not have the bright, clean, aluminum-like finish characteristic of sand. Where surfaces of metal are to be cleaned, enameled or japanned the use of sand becomes imperative. This is due to the fact that by the use of the proper sand and air pressure a "tacky" surface is obtained, on which the coating medium secures a firm hold. This so-called "tacky" surface is caused by the sharp corners of the sand digging up the surface of the metal as if a myriad of small sharp punches had been at work. With the use of crushed steel the opposite or "peening" effect is given to the surface.

For producing the satin finish on plated articles, as well as for etching on glass, very fine sand and low air pressure is used. For producing the satin finish on machined articles it is possible to use a higher pressure and slightly coarser sand, and for this purpose lake sand is sometimes used.

For the cleaning of work like steel cars, sand which will pass through a ten or twelve mesh screen is frequently used, though in some cases ordinary river sand is used. For preparing work for enameling, sand which will pass through from an eight to twelve mesh screen is employed.

For the cleaning of iron and steel castings quite a wide diversity exists, as in some places only the very coarsest sand, that which will pass through a three mesh screen or even coarser is used; whereas at another plant doing the same kind of work, sand which will pass through a sixteen mesh screen is used with equally good results. So that the kind, quality, and grade of sand

depends largely on local conditions, which can be found to best advantage by experiment.

In some places the sand is used only once and then hauled to the dump. Where this is done a grade of sand is usually used which breaks up to a large extent and only a small percentage would be fit for re-use. Sand of this description can be used where the cost of delivery at the plant is low and the duty required of it is not severe.

Air Pressure.

As with other things, the air pressure required has been the subject of considerable controversy among sand blast manufacturers. If we are to take into consideration some of the advertising of the manufacturers of sand blast equipment, we would find that where one manufacturer claims to be able to prove by "scientific experts" that fifteen pounds is amply sufficient, another manufacturer states that steel castings should have a pressure of not less than ninety pounds, while for cleaning iron in "malleable" a pressure of at least eighty pounds at the sand blast is desirable. This will tend to indicate that some of the sand blast manufacturers are not sure of their ground.

The writer sent a circular letter to quite a large number of foundrymen who were using the sand blast for cleaning castings and in only one instance did they reply that they were using as low as eighteen pounds, while some replied that they were using in excess of one hundred.

There are a number of reasons why the so-called high pressure sand blast is not desirable. One objection is the excessive cost of air delivered at the nozzle. This will include the greater horse power required for compressing the air; greater cost of repairs and greater loss of air from leaks. Another feature which is against economy in the use of "high pressure" is the very much greater amount of sand rendered unfit for use by being disintegrated or broken up. That this feature cannot be neglected or overlooked needs no explanation. Recently the manager of a large plant informed the writer that with about eighty pounds of air, their loss in sand amounted to six dollars per day.

With a nozzle projecting a small stream of sand there is no doubt but that a high air pressure must be used. The small

stream cleans a narrow strip and in order to clean with any reasonable speed the operator must watch his work carefully. But where a larger volume of sand is used the air consumption is somewhat less, while the surface is covered much more rapidly. This of course means more economical results for the foundryman.

When high air pressure is used there is another disadvantage which must not be overlooked. This is the greater amount of dust caused by the excessive breaking up of the sand. This seriously interferes with the vision of the sand blast operator, making his work slower. The practical manager will readily see that these are valid objections to the use of high pressures.

Sand Blast Nozzles.

With the ordinary nozzle as used by sand blast manufacturers it is a question of only a few hours until its inside diameter is very much increased and consequently the air consumption is enormously increased. As the kind of labor very largely used for operating sand blast is of the poorest class, the nozzles are frequently used until worn so that they consume much more than double the original amount of air per minute. That this is very expensive goes without saying. However, there is one nozzle on the market to-day which is in use in a number of plants and which possesses advantages over any of the others. This nozzle can be adjusted to consume a determined amount of air and when so adjusted the air consumption in cubic feet per minute will be the same after months of use as when first installed. The life of this nozzle is indefinite.

The writer recently saw one which had been in use for a period of eight months and was then in good condition, showing scarcely any wear. At several large plants where nozzles of this description are in use a series of experiments were conducted which demonstrated that a pressure of forty pounds was amply sufficient to clean their steel castings and do so economically.

A casting can be cleaned by passing the nozzle over it at a certain speed. If this speed is exceeded the casting will not be cleaned; while if the speed is lessened there is a loss of efficiency. Again, an operator can pass the nozzle over a casting at a certain speed. An air pressure in excess of what is actually required to clean at this speed is an absolute waste.

Another point which has not been heretofore taken into consideration has been the one of the punishment of the operator when the coarse sand is used with high pressure; the coarse sand in some instances rebounding from the surface of the castings with such force as to pass entirely through glass one-quarter inch thick. This is energy expended for no useful purpose, and therefore a waste. The writer has seen castings whose surface after being cleaned by sand blast had an appearance of having been peened with a small hammer. This is another result of the combination of high pressure and coarse sand.

Sand Blast Machines.

For the class of work commonly known as "flat" work sand blast machines are quite successful. Generally speaking, there are two styles: the rotary and the reciprocating.

The rotary machine consists of a horizontal circular table revolving about a vertical shaft. This table has its surface formed of gratings, through which sand blast may fall after being used. This table is only partially exposed; about one-half of it being covered by a box-like enclosure, within which the sand blast nozzles are placed.

These nozzles are given a reciprocating motion by means of suitable mechanism. The table revolves slowly and the castings placed upon it are passed underneath the moving nozzles, where they are subjected to the action of the sand blast. The used sand passes through the grating in the table top to a hopper beneath, from which point it is elevated, cleansed from dust, screened and returned to the nozzles for use again.

After having passed underneath the nozzles the castings are turned over on the table by the attendant and they pass underneath the nozzles again. This in brief is the method of operating the rotary sand blast machine.

The other style is similar except that the table on which the work is placed is given a reciprocating motion instead of a rotary. In a machine of this description the table passes underneath the nozzles to the other side of the machine; the mechanism then reverses its direction and it returns. The mechanism controlling the movements of the nozzles, sand, etc., is similar with either style of machine.

For fittings and small miscellaneous castings ranging in weight from a fraction of an ounce to about one hundred pounds, the above mentioned machines would not be suitable nor economical, and therefore an entirely different type of machine was designed. These are usually known as:

Sand Blast Barrels.

There are two styles of sand blast barrels; one kind having its axis inclined at an angle, while the other has its axis horizontal. There are a number of different forms of the horizontal type. One form has a series of nozzles, five or six in number, extending downward from a horizontal header, which extends lengthwise of the barrel. This barrel has an inner lining perforated with small holes. The used abrasive material falls through these perforations into the space between the outer shell of the barrel and the lining. As the barrel slowly revolves this material is carried upward until it falls through the perforations again into a hopper placed on top of the beforementioned header. From this hopper it again passes down by gravity through the nozzles. In this manner it is used over and over.

The dust is removed by means of an exhaust fan.

Another type consists of a horizontal barrel with perforated shells and openings in the center of the heads. This barrel is slowly revolved at a speed of from two to four revolutions per minute. Sufficient castings are placed within the barrel to only partially fill it. As the barrel slowly revolves the castings in falling over and over each other are exposed to the action of the sand blast, which is directed upon them through the opening in the head. The barrel is entirely inclosed in a casting which prevents sand blast sand from flying about and retains the dust.

The dust, small bits of castings, and the abrasive medium escape through the perforations in the shell and fall into a hopper placed beneath. From this hopper the sand is removed, screened and returned to the machine for farther use. The casing should be connected to the exhaust fan in order to remove the dust.

In the sand blast mills it is impossible to fill the barrel entirely in order to give the blast an opportunity to take effect on the moving castings. Mills of this description possess several distinct disadvantages; one is on account of being fitted with nozzles which

require frequent replacement. In mills of this kind the castings fall over and over each other as the barrel slowly revolves; the castings from the top being precipitated to the bottom of the shell. This therefore precludes their use for delicate castings, especially malleable castings in the "hard," before being annealed.

Fig. 1 is a side elevation of a sand blast mill of the inclined type. In mills of this description the castings do not fall over and over each other, but instead, due to the inclination of the barrel, slide gently over each other. This permits the sand blasting of delicate castings which cannot be sand blasted in the horizontal type. Barrels of this description possess another distinct advantage in that they are fitted with nozzles which have practically *no wear*. Therefore they can be used for months without repairs or replacement of nozzles. Another advantage is that these nozzles have the same air consumption in cubic feet per minute at the end of months of use as when first put into service.

Notwithstanding arguments to the contrary, in practice the above described barrels equipped with these nozzles have cleaned castings which have been declared by practical foundrymen to be impossible to clean in mills of this description. It is not necessary with these nozzles to use an extremely high air pressure. On the contrary, forty pounds has been found to do very thorough and rapid work. Two of these barrels have demonstrated in practice to be capable of cleaning from fifteen to twenty tons per day of castings ranging from a fraction of an ounce up to about one hundred pounds in weight.

Such record was obtained under ordinary everyday working conditions and not for any special experiment. This too in face of the fact that they were so placed that it was necessary to charge them by hand, and after the mill was emptied the castings had to be removed in the same manner. If these mills had been equipped with suitable arrangements for quickly charging and removing the castings their capacity would have been greatly increased.

The door for discharging the castings can be opened, the mill emptied and the door replaced in one minute with a proper arrangement of a changing device. There is no reason why the mill cannot be emptied and recharged and the door replaced in

considerably less than two minutes. This is a record not excelled by another.

Recently the manager of a large malleable iron works wherein two of these barrels were installed made the statement that for cleaning castings to prepare them for galvanizing he was able

FIG. 1.

to reduce the cost by means of these barrels to almost one-fourth of what it formerly cost by means of the ordinary acid pickling process. Under ordinary circumstances one is safe in saying that the cost of preparing casting for galvanizing by means of the sand blast process in these mills can be reduced to at least one-half of the cost of preparing the castings by pickling.

Sand Blast Rooms.

Castings which are too large for the above-mentioned mills must be cleaned in an entirely different manner, and for this the sand blast room should be used. There are different arrangements of sand blast rooms of varying degrees of efficiency, possessing disadvantages according to the arrangement. A short time since a sand blast room was shown as the latest example of modern practice. In the roof there were a number of hoods or funnels which were connected with pipes to an exhaust fan. Beneath the grating in the floor were also several exhaust pipes connected to the exhaust fan. The idea being that if there were a sufficient number of exhaust pipes the dust would be removed from the room. However, it did not so develop in practice. This was due to the fact that there was no well defined current of air from the room, part of the dust being drawn upward in various directions, part being drawn downward. A canvas door was used to permit the free entrance of air and to prevent the sand blast sand from being thrown out.

As a matter of fact, after the sand blast machine was shut down it took a considerable length of time to remove the dust, as air would be admitted through the large openings and would pass directly to some of the exits without disturbing the large body of dust.

Another feature was that there was no provision made for the handling of the sand blast sand which simply fell through a grating in the floor into the pit beneath. From this pit it was shoveled out by hand, screened, and shoveled into the machine. Such an arrangement was not modern, efficient, nor economical.

Another method of arranging the sand blast rooms has been to allow the sand to pass downward through a grating into a hopper which directed it into the boot of an elevator, which carried it overhead to a series of revolving screens which in turn delivered it to a receptacle or bin, after which it was allowed to run into the sand blast machine.

This method, while in advance of the one previously described, possesses several disadvantages, among them being the amount of machinery required. This includes bearings, conveyors, screens, etc., subjected to the action of the sand. Another dis-

advantage is the depth of pit required. Where the manufacturing plant is located on low ground, as very many are, or where the soil is of a sandy nature, the item of a deep pit means considerable from the difficulty and expense of digging and concreting the pit.

Another method which seems in advance of all others is one in which the room is tightly closed and air admitted only from the top through ventilators. These ventilators are of special design so that sand will not be allowed to pass out through them. The air is changed about six times per minute and is drawn from the room from beneath the floor grating, admitting a strong, well-defined downward current. In this manner the dust is drawn from the room.

Due to the strong downward current of air, the dust does not rise to any height, but usually remains at about three to five feet above the floor. With a room arranged in this manner, within a few seconds after the sand blast machine has been shut off it is entirely free from dust. With this arrangement the same current of air which is used for ventilating the room is also used for the elevating of the sand. With the full equipment used with this system the sand passes down through the floor grating into the hopper beneath, from which it is allowed to pass into the ventilating pipe by a special design of feeding device which does not permit the pipe to become choked.

Should the fan be suddenly stopped while there is considerable sand in the hopper no harm can result, as the feeding device does not permit the sand to run into the pipe; as a matter of fact, it only allows the sand to enter as rapidly as it is elevated by the air. With this arrangement when it is necessary to add sand to the supply it is only necessary to throw the same down through the floor grating into the hopper, from which place it will be elevated to the sand separator device placed overhead. This separator retains the sand which is used for sand blasting and permits the dust and fine sand to pass onward to the dust arrester, where it is retained in bins provided for the purpose.

This separator does its work without moving parts, screens, etc. This device is capable of adjustment so as to retain sand of varying degrees of fineness.

Sand Blast Machines.

Usually a sand blast machine is a source of considerable trouble and annoyance. This seems to be due to a variety of causes, but in many cases it is due to too many machined and fitted small parts. Labor with which the sand blast room is usually operated is of the poorest class and consequently sand blast machines should be made as nearly "fool proof" as possible. In other words, sand blast machines in general have entirely too much machinery about them. The fewer and less refined the parts are the better for their operation.

Sand blast machines usually have some sort of a fitted cover or valve at the top through which the sand must be fed. This is a source of constant annoyance and trouble and very frequently cuts out around the cover in a very short time. Some sand blast machines have at the top an opening closed by a plug which is screwed in place. We all know what happens when fine sand gets into a machined thread, and we can form an idea as to what will result unless the plug is tightly closed. This can be remedied by a specially designed valve fitting to a corresponding seat. By properly designing the valve and seat it is possible to make the opening of the valve automatic, *i. e.*, when the sand blast machine is shut off, as soon as the pressure becomes reduced a sufficient amount, the valve will automatically open.

Such machine when connected to one of the above-mentioned sand separators will be automatically filled without any attention whatever from the operator, as soon as it is shut off. With this system properly installed the operator need pay no attention whatever to his supply of sand or to the screening of the same, as all that is done automatically as the machine is refilled without any attention from the operator. This effects a considerable saving of time and labor. A machine which operates in the manner above described is shown in Fig. 2.

In the description of the sand blast mill shown in Fig. 1, mention was made of the nozzles with which these mills were fitted. A similar nozzle has been designed for use in sand blast rooms. While not applicable to all conditions, yet under suitable working conditions it has proven that it possesses many distinct advantages over the other nozzles in use. This nozzle possesses the advantage

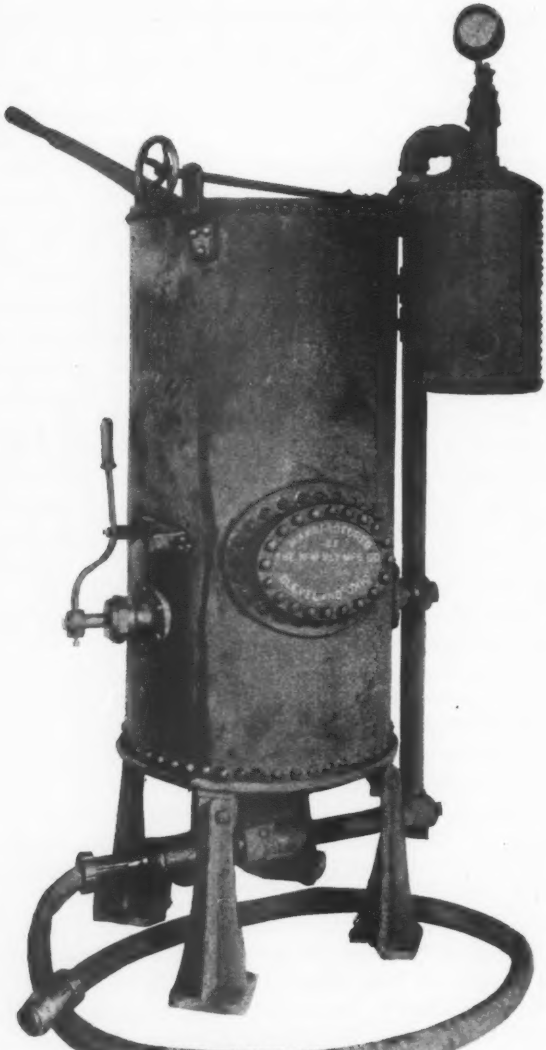


FIG. 2.

of having a very long life and at the end of its life uses the same amount of air as when first put into operation.

For the cleaning of general work it is rapid and highly efficient. In Fig. 3 is shown an arrangement of a sand blast room complete with sand elevating pipes, sand separator and dust arrester complete. The nozzle just mentioned is attached directly to the sand separator; in this manner it has a constant supply of sand and therefore can be operated without interruption for long periods of time. Should it be desirable to use a high pressure machine instead of the nozzle shown, the separator can be connected to the machine in the manner described above. It will be noted that the arrangement shown in Fig. 3, *a* and *b*, possesses the following advantages:

1. Shallow pit; this means low cost of installation.
2. Absence of machinery for elevating or conveying the sand.
3. Absence of machinery or moving parts for screening and separating the sand from the dust.
4. Freedom from dust; in this arrangement separating as described above, the dust is not permitted to escape into the surrounding atmosphere, nor is it allowed to accumulate in the sand blast room, but is almost entirely removed; air from the exhaust fan being so nearly free from dust that it may be returned to the work room. This effects a saving of heat in winter time. It may also be used for a hot air heating system.

In the past the amount of work done in the sand blast room has been only too small. This has been due to a variety of causes; mostly to improper arrangement and inefficient operation. The rooms were too frequently allowed to remain idle for perhaps seventy-five per cent of the time. This was due to crude methods for filling the room with castings and for removing them after being sand blasted. Long periods of time were consumed in riddling the sand by hand and shoveling the same into the machine. Frequently the machine had to be emptied on account of some piece of wire or bit of casting getting into the machine and stopping it. Thus the sand blast installation, instead of being a source of profit and shall I say pleasure, it became a constant source of expense, annoyance and trouble. With a proper installation all this can be changed, and time and money saved in its operation.

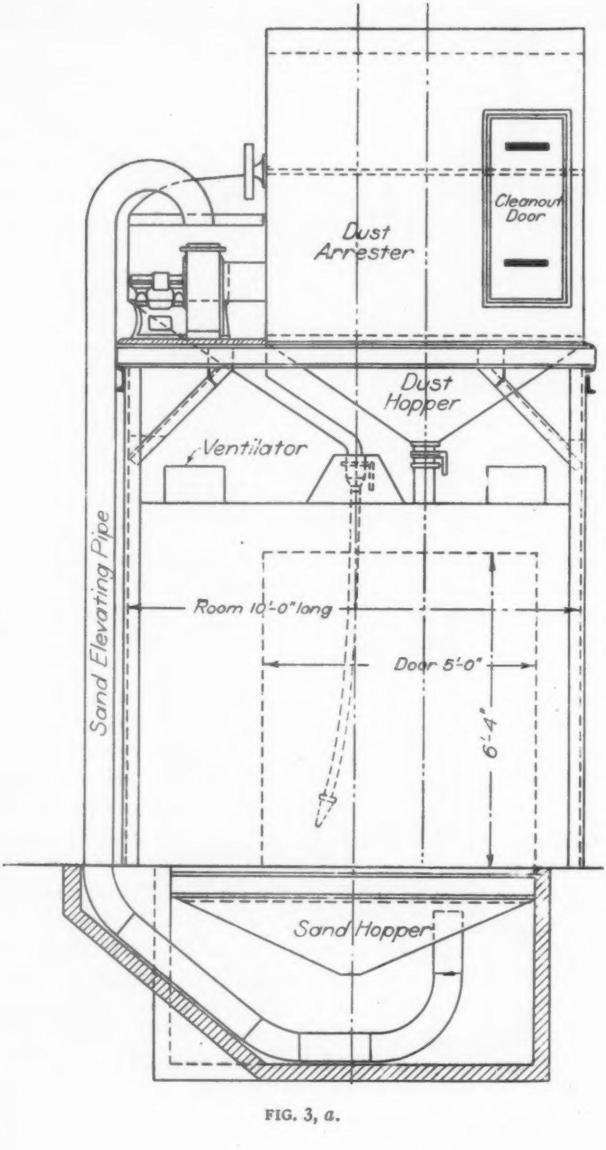

Cleanout Door
Dust Arrester
Dust Hopper
Ventilator
Sand Elevating Pipe
Room 10'-0" long
Door 5'-0"
6'-4"
Sand Hopper

FIG. 3, *a*.

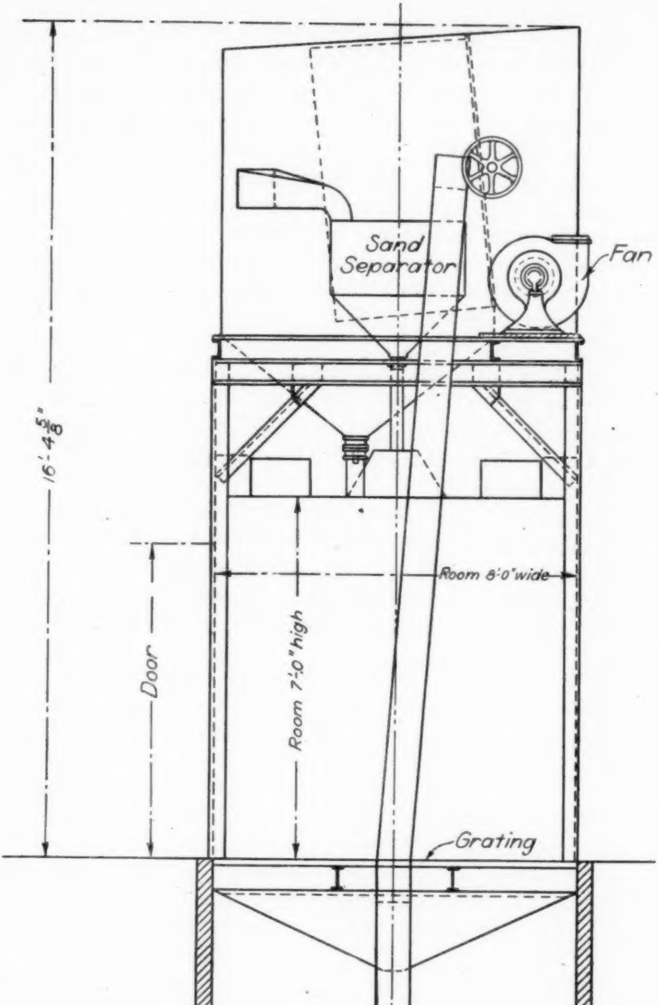

Sand
Separator
Fan
16' 4 5/8"
Room 8'0" wide
Door
Room 7'0" high
Grating

FIG. 3, *b*.

Serving the Sand Blast Room.

This has been economically accomplished in several ways, which of course depend on the requirements of local conditions. In several instances the castings were taken into the sand blast room on a trolley suspended from an I-beam supporting the roof of the sand blast room. This I-beam track was continuous. The sand blast room was provided with a door on either side; therefore, as soon as the casting or set of castings were sand blasted the doors opened and the cleaned castings pushed out of the room at the same time other castings were brought into the room from the opposite side. In this way the room was operated nearly continuously, there being scarcely any time lost in handling the castings. Again castings are handled on trucks which are pushed into the room on one side and pushed out on the opposite side; the tops of the cars or trucks usually being formed of bars or gratings. Under the conditions under which this has been operated it has proved very successful.

Another method is where the castings are brought into the room on skids which extend through the room as an elevated track. In this way the castings are removed and replaced very rapidly. As stated before, the complete sand blast installation should be designed specially to meet the requirements of each particular location.

THE HEATING AND VENTILATION OF THE FOUNDRY.

By W. H. Carrier, Buffalo, N. Y.

Manufacturers in general realize more to-day than ever before that one of the greatest assets of a business, in that it is an efficiency producer, is the proper and adequate heating and ventilation of the work rooms, foundry, machine shop and offices. No cost-keeping system, no bonus plan, no welfare work, in fact, no system of modern efficiency will be complete or successful until first and foremost the comfort of the employee is considered.

The problem of heating the machine shop or office is not to be approached from the same angle as that of the foundry; in other words, the conditions surrounding the workers are different and I always think that to be a success as an engineer, like the successful actor, you must throw yourself into the part. You must imagine the conditions and then work to their proper solution.

What are the conditions in the foundry? Let us consider a cold winter's day. The molders will not work efficiently if their fingers are stiff and bungling. The craneman cannot operate in the most expeditious manner during the "pour" if surrounded by dense vapors and smoke. The workmen will not feel in the best of physical condition if they have to resort to huddling in the poison-laden air around a "salamander." The working of frozen sand will not be conducive to quality in the product.

The feature governing the design and selection of the foundry heating and ventilating system may be enumerated as follows:

1. Desirable temperature.
2. Even distribution of heat.
   - (*a*) Prevention of cold drafts.
   - (*b*) Economical applications of heat to avoid radiation of heat out of doors, and over-heating of unoccupied space.

3. Ample ventilation when needed.
4. Rapid heating up of building in the morning.
5. Cost of installation.
6. Economy of operation and maintenance.

The desired minimum temperature in the foundry depends largely on the nature of the work; small work requiring a higher temperature than heavy work where there is considerable physical exercise. In general, however, the temperature required in the

FIG. 1.

foundry is from five to ten degrees lower than that which would be suitable for a machine shop,—that is, the desirable temperature lies between 50 and 60° F.; 55° may be taken as a good general average.

The proper distribution of heat in the foundry is comparatively difficult. In general, the problem is that of a large open space, affording little opportunity for efficient placing of direct radiation. On account of the usual monitor type of building employed, there is relatively a great height. The hot air rises up into the lanterns and out through the ventilators if fans are

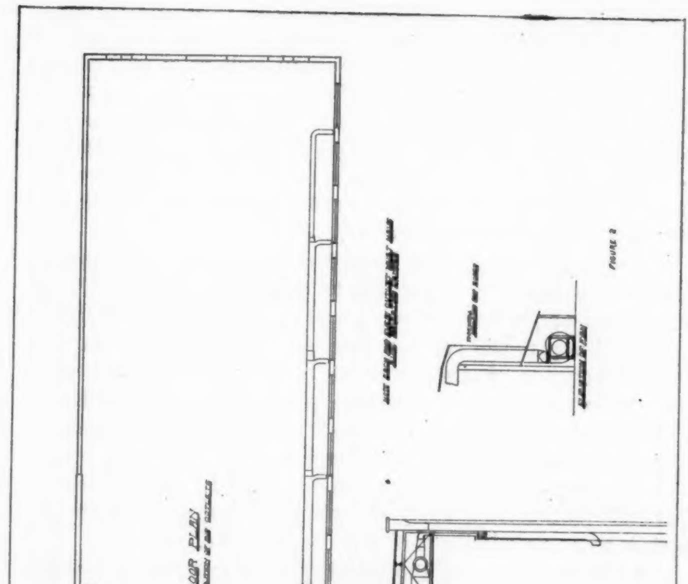


FIG. 2.

not provided to keep it down near the floor. The heated column of air in the building acts like a chimney, drawing cold air from without at every opening. This inward leakage of cold air not only demands a great amount of heat, but makes a thorough distribution of heat at the floor line most essential for comfort and economy of operation. A slight plenum or outward leakage of air at these doors and openings, caused by the delivery and proper distribution of sufficient heated air into the building, is the only solution of this difficulty.

Ample ventilation is at times most necessary. The lantern type of building is best adapted to quickly ventilate, since the ventilators simply have to be opened and the hotter and lighter gases and vapors will rise and pass out. The fact must be considered, however, that air is bound to come from somewhere to take the place of the atmosphere passing out the ventilators. Cold outside air through the doors and openings will tend to cool off and condense the rising vapors to an even more serious and clouding extent. It is therefore essential that a system be installed that delivers fresh air, warmed, during those pouring periods when ventilation is of prime importance.

Rapid heating up of the building in the morning means that the best efficiency from the men will be obtained over the entire working period. A system which is elastic and capable of rapid and accelerated results is to be favored.

Coke or gas fired "salamanders" are apparently the most economical form of heating, as all of the heat goes directly into the building. The atmosphere in a tightly closed building heated by this method becomes intolerable, and if sufficient ventilation is provided to make conditions healthful, then the amount of heat required is greater than with other systems. The grade of fuel required is also considerably more expensive than other systems of heating, to say nothing of the care of a large number of separate fires scattered around the building.

In heating with direct radiation, steam is usually employed, although hot water systems with forced circulations have been successfully operated. Unless there are large amounts of hot water available it is not an economical system to install on account of the greatly increased amount of radiation which is required at the lower temperature. In steam heating either the high

pressure, the low pressure or the vacuum system of distribution is employed, the selection of the particular system depending on local conditions. Where high pressure system is available and there is no exhaust steam, high pressure steam should be used because steam at 100 lbs. gives approximately 75 per cent more heat per square foot of radiating surface than steam at 5 lbs.

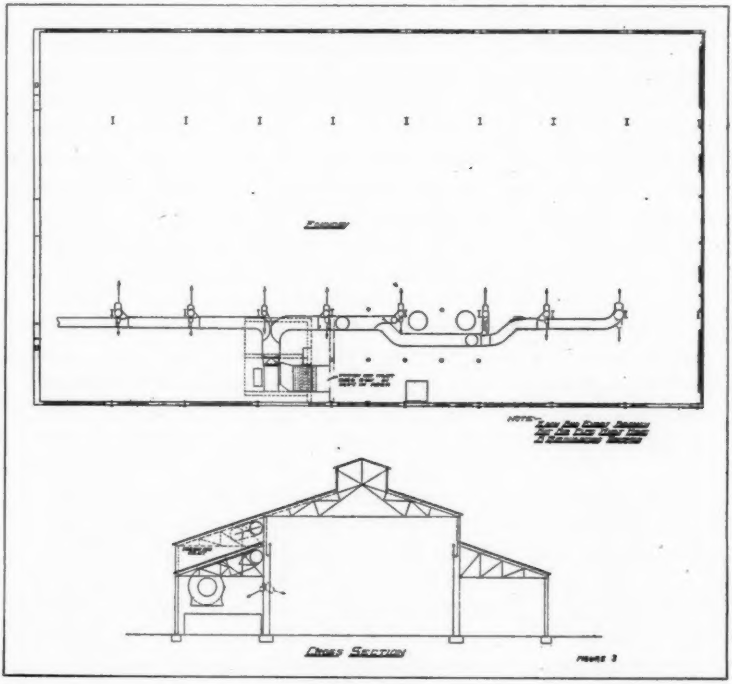


FIG. 3.

owing to its higher temperature. However, if there is no high pressure steam or exhaust steam available from the power plant, then an independent low pressure boiler should be installed to furnish steam at from 5 to 10 lbs. pressure. For low pressure work cast iron boilers may be used, and no boiler feed pumps are required. The boiler should be placed at a level so that the

condensation will drain back by gravity. If this is impracticable, then a gravity system may be employed by using a centrifugal pump to raise the water level to that of the boiler. A vacuum system should always be used when exhaust steam from the power plant is available. In a vacuum system of distribution the back pressure should not exceed 1 lb., as otherwise the power of the engines will be reduced and the steam consumption increased.

Probably the most satisfactory method of arranging the direct radiation is that of mitre type coils placed along the outside walls between the windows, the main lengths of the pipe being vertical, to avoid accumulation of dust and to obstruct the side walls as little as possible. Several rows of pipe are also run along the side wall of the monitor roof just above the crane. This is to provide for the radiation of heat through the roof and skylights and to prevent cold down draughts which would otherwise occur. Such distribution of radiation is not efficient, but it is the only practicable method in this type of building.

The best system for foundry heating and ventilation is undoubtedly the fan system, and it is particularly adapted to the severe requirement of foundries and other buildings of this construction where there are large open spaces to be heated. The principal advantages of a fan system over direct radiation are:

1. The thorough diffusion and distribution of heat secured by discharging the air under pressure through suitable outlets, with sufficient velocity to carry the heat through the points where it is most needed without causing perceptible draughts.

2. No heat is wasted as in direct radiation where a large portion is radiated directly through the walls out of doors without affecting the temperature of the building. The fan system affords a means of supplying heat directly to the air itself.

3. No heat is wasted by heating unoccupied space, as along the roof and in the monitors. Tests of fan systems installed in foundries have in certain instances shown lower temperatures in the monitors than at five feet above the floor line.

4. Fan systems heat up very much more rapidly in the morning when it is desirable in point of economy to bring the temperature up in as short time as possible.

5. It gives a rapid warm air charge which effectually removes

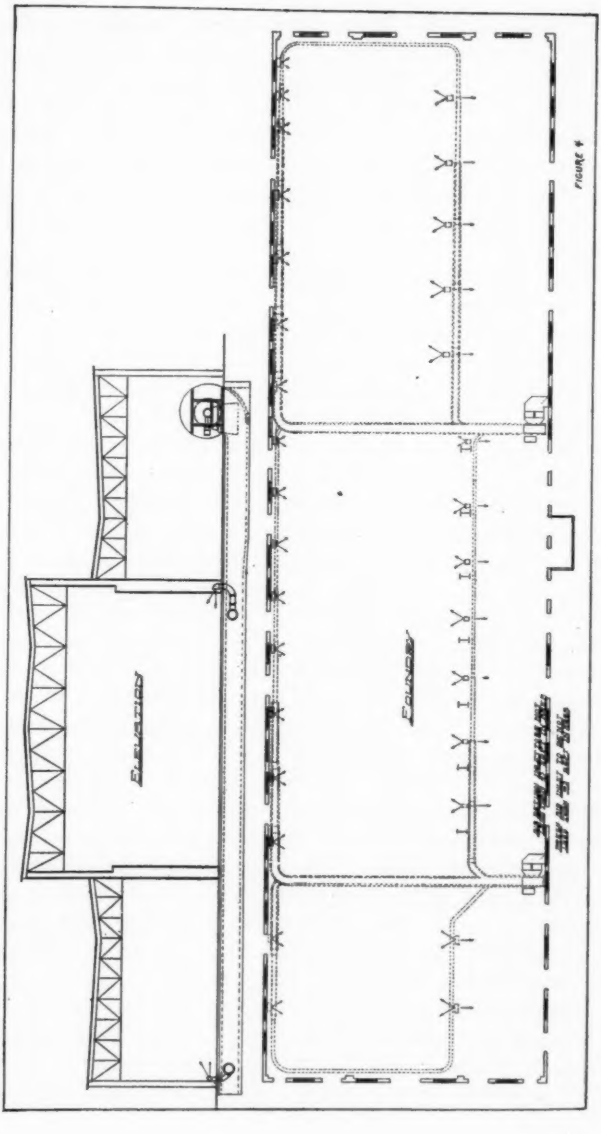


FIG. 4.

smoke, steam and dust during pouring times, an effect which is possible only with a fan system. During such times as ventilation is required, the fresh and return air dampers would be adjusted to take all air from out of doors. During the balance of the time, however, the greater part of the air should be returned from the building to the apparatus so that the heat required for ventilation is a minimum. Purchasers should always take a precaution to see that this feature is provided for in a proposed installation.

6. Fan systems cost less to install properly, since the apparatus is centrally located and it is not necessary to pipe the steam to all parts of the building as in direct radiation.

7. The cost of maintenance is less, since radiation along the walls is frequently damaged while in the centrally located fan apparatus it is thoroughly protected.

Just as in direct radiation, steam or hot water can be used in the fan system heater coils. The fact that the cool air is drawn over these coils by the fan, makes it possible, however, to obtain a great deal more heat from the same amount of heating surface. This cuts down the square feet of radiation about two-thirds.

Very often the fan is driven by a direct connected steam engine, the exhaust steam from the engine being used in the heater coils. This is an exceedingly economical procedure, as practically every heat unit of the steam is utilized.

The Buffalo Forge Company has been particularly successful in developing a new form of fan system heating, namely, the direct air furnace system. Instead of burning coal, gas or oil under boilers, developing steam, transferring the steam from boilers to heater coils through possibly a considerable run of pipe and finally giving up the heat to air from the heater coils, this system transfers the heat of the burning fuel directly to the distributed air. An efficiency of 85 to 90 per cent has actually been obtained, as against the usual 50 to 60 per cent resulting from steam boiler operation.

Numerous installations have been made, using gas for fuel, and recently a system using powdered coal has been installed. Fuel oil could also be readily adapted. The construction of the furnace is similar to a horizontal water tube boiler. The hot

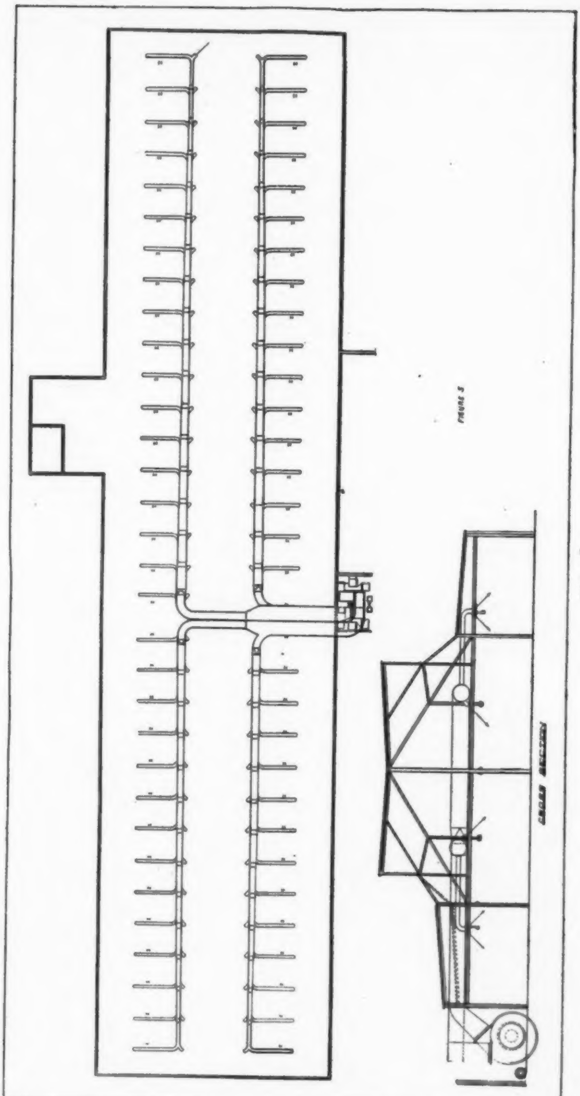


FIG. 5.

gases pass through the tubes and the circulating air is drawn around the tubes by the supply fan, heated and distributed. Fig. 1 is an illustration of the furnaces installed at the plant of the American Rolling Mills, Middletown, Ohio.

The main hot air ducts from the fan are usually of galvanized iron carried overhead in the roof trusses. When these ducts are placed in a height not exceeding twenty feet the air may be delivered into the building through short outlets. The design of these outlets is of particular importance to the success of the system. The velocity must be properly proportioned to the height, to the size of outlet and to the horizontal distance which the air is to be blown. The greater the distance and height above the floor and the smaller the outlets, the higher the velocity must be to obtain the proper distribution. On the other hand, if the velocity is excessive for these conditions, objectionable drafts will be produced.

In certain cases, as in Fig. 2, the main piping has to be placed too far above the floor to admit a good distribution of heat at the floor line with short outlets. In such cases it is usual to provide drop pipes from the main pipe at the columns or along the side walls. Where the drop pipes are placed at the columns each is usually provided with two branches; one blowing towards the base of the windows at the side wall, the other blowing towards the center of the building, as in Fig. 3. Where the drop pipes are extended downward at the side walls, it is usual to provide three outlets to each drop pipe, two blowing sidewise along the walls and the third blowing outward towards the center of the building.

In wide buildings it is usual to run two lines of pipes along the columns on each side, while in narrower buildings it is possible to obtain an entirely satisfactory distribution of heat with one line of main pipe having outlets proportioned to blow across the building to the further side, as in Fig. 3.

A very neat though a more expensive system of distribution is with underground main ducts with galvanized iron vertical risers, arranged along the columns or side walls, or in some instances, as particularly wide buildings, at both places. (See Fig. 4.) The system of outlets in this case will be practically the same as where drop pipes are used.

Fig. 5 shows the arrangement employed in one of the

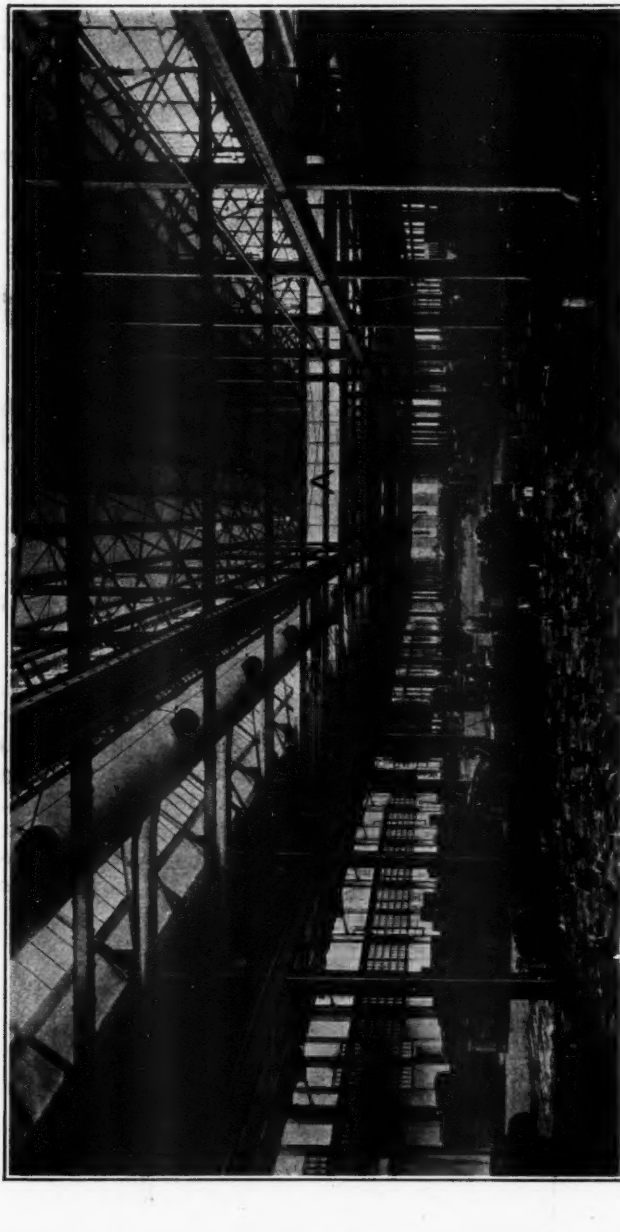


FIG. 6.

large foundries in the country, that of the International Harvester Company, Springfield, Ohio. The building is very wide, as well as long, and distribution is made at four points across the building instead of one or two as is customary. Fig. 6 is an interior view of the same building showing some of the overhead ducts.

Fans may be either motor or engine driven. When plenty of exhaust steam is available for use in the heater coils the motor driven fan will be found most economical and satisfactory. It is also preferred by many on account of the great simplicity of operation and the little care and attention needed. On small fans it is good practice to directly connect the motor to the fan but on the larger apparatus the speed of operation is so low as to make it advisable to belt drive the fan, due to high cost of slow speed motors.

Engine driven fans are advisable when moderately high pressure steam is easily available. The steam can first be used to drive the fan and then the engine exhaust used in the heater coils. This procedure is exceedingly economical, since practically every heat unit if the steam is utilized. The power used to drive the fan is almost negligible, as the engine is really nothing more than a pressure reducing valve. The speed of operation with engine drive is also much more flexible, allowing a wide range of speed such as different weather conditions require.

In closing, no doubt a few words concerning the cost of the various heating systems would not be amiss. Direct radiation and the fan system of heating cost practically the same to install; the fan system, the power necessary to drive the fan, is additional and to the casual observer it would seem that the operating expense would be somewhat more than with direct radiation. The fact that the heat is distributed more efficiently with the fan system, cuts down the losses and necessary radiation materially, however, and the net operating expense of the two types of systems varies very little in the long run.

THE CLEANSING EFFECT OF TITANIUM ON CAST IRON.

By Bradley Stoughton, New York City.

Introduction.

This paper gives the results: first, of a research into the somewhat extensive literature of titanium; and, second, of a series of original tests upon the effect of titanium on iron castings. New investigations have also been made upon the effect of titanium on steel castings, but I hope to treat this subject in an independent paper at some later date, and therefore will not discuss the experiments in detail here.

The combined results of this study, which extended over a period of more than two years, can be briefly summarized in the following three counts:

First.—Steel and cast iron, in which the titanium is properly proportioned, and which is properly treated, is improved in strength, toughness and durability against wear—such as, for example, the wear of railroad rails, of steel and chilled iron rolls, car wheels, etc.

Second.—These improvements seem to be caused, not so much by the direct effect of titanium on the metal, as by its cleansing influence in removing harmful impurities, such as oxygen and oxides, nitrogen, occluded slags, and perhaps also sulphur. It appears also to reduce segregation, which would contribute to the same end.

Third.—In order that its effects may be fully realized, the treatment of steel or iron with titanium must be correctly performed. There are a few simple, but essential, details to be observed; if they are neglected the best results cannot be expected. This has been taught me, not only by my own experience, but also by the experiments of others.

To illustrate by an example: A series of tests on cast iron was carried on in a German foundry, in which scientific apparatus

and instruments were employed and great care apparently exercised in executing the work, but the titanium treatment was performed without a knowledge of the conditions which should have prevailed, and, as a consequence, the results were inconclusive. It is as if one should attempt to boil water with the best adapted appliances obtainable; with scientific instruments to measure the temperature and regulate the operations, and with every condition fulfilled except heating the water to a high enough temperature. Obviously, the result would be quite as unsatisfactory at 211° F., as far as boiling water is concerned, as at 60° F., although the former point is within a hair's breadth of success. So, in adding titanium to iron or steel, if it is put into the slag instead of the metal, or if opportunity is not given for it to be absorbed and do its work, or if the steel is subsequently allowed to become oxidized, or if the treated metal is cast much too hot or much too cold—if any, or all of these important details are neglected, we must not expect to get the best results.

This paper is presented at one and the same time to the American Foundrymen's Association and the American Institute of Mining Engineers. In the *Transactions* of the latter society many data and references are published in detail which are given here only in condensed form, and one should refer to this detailed paper for more complete information and for proof of several statements that are made here, if such statements seem to require more proof.

Occurrence.

Titanium has often been spoken of as one of the "rare elements," but this description is true only in the sense that the metal is seldom met with in nature and in the arts under its own name and identity. This is because it unites with extraordinary eagerness with both the oxygen and nitrogen of the atmosphere, and with other elements and metals prevalent in nature, and because it can be separated from its combinations with much difficulty, so that it has never been found in the free state and has only rarely been reduced from its compounds by artificial means. In every other aspect it is far from being rare: a reliable estimate places it among the ten commonest elements in the earth's crust, together with oxygen, aluminum, iron, silicon, etc. It has often been recognized in plants, in the human blood, in meteorites, in the

spectrum of the sun, and elsewhere, and it is frequently found in clays, where it has the effect of increasing their fusibility.

Chemical Properties of Titanium.

The chemical properties of titanium are in general similar to those of silicon with this difference: that titanium is more active in combination both as to the number of elements with which it unites readily and the number of different compounds formed with each. In some respects it is also far more energetic in its action than silicon, as for example: it unites with oxygen, nitrogen, chlorine and bromine with so much energy as to become red hot.

It unites readily with oxygen at 610° C. (1130° F.), and this reaction evolves 79,772 Cals. It is one of the elements, like sodium, etc., which, when brought into contact with water, decomposes the water to form hydrogen gas and metallic oxide. Upon warming powdered titanium it unites readily with oxygen with brilliant scintillation and the reaction is so energetic that it carries itself on thereafter even if removed from contact with the flame.

Woehler states that he does not know of another body which burns as energetically in oxygen as titanium, and furthermore, that metallic titanium mixed with oxide of copper and warmed, reduces the copper to the metallic state with the evolution of great heat. It forms many oxides, such as TiO, Ti_2O_3, TiO_2, etc., of which TiO_2 is the most common. The oxide of titanium is reduced by aluminum with a small evolution of heat.

Titanium has a greater affinity for nitrogen than any other known element. When heated to 800° C. (1472° F.) in an atmosphere of nitrogen gas, it burns brilliantly with incandescence. Robert Austen states that it is the only known instance of vivid combustion in nitrogen. It forms several nitrides such as Ti_3N, TiN, Ti_2N_3, Ti_3N_4, Ti_3N_5, etc.

Titanium also forms a stable carbide, TiC, which has been found in pig iron and ferro-manganese, but which is said to be almost absent from ferro-titanium, that is to say, from pig iron when the titanium is large in amount—say over 10 per cent. Indeed the action of titanium is to precipitate carbon from cast iron and steel.

Titanium forms one stable sulphide: TiS_2. Blair and Shimer

found crystals of the following composition in a gray pig iron: Ti. 62.82 per cent; S. 22.64 per cent; C. 9.82 per cent; Fe. 1.82 per cent; unaccounted for 2.90 per cent. I am inclined to think that titanium sulphide is not readily soluble in molten iron and steel, but, like manganese sulphide, it separates from the molten bath. But the action seems to be more rapid in the case of titanium sulphide than in the case of manganese sulphide, because Goldschmidt and Treuheit found the amount of sulphur slightly decreased after a brief titanium treatment.

Titanium unites with chlorine, fluorine, iodine, hydrogen, etc.; also it forms an aluminide, silicide, boride, etc., but has only slight affinity for phosphorus and arsenic.

The oxide of titanium acts as an acid flux and unites with oxide of iron, aluminum, calcium and other metals to form titanates. These titanates apparently lower the melting point of silicates of the same metals; *i. e.*, the dirt and slags occluded in iron and steel.

Titanium in Steel.

What is now called "titanium steel" is not a true alloy steel in the same sense as nickel steel, manganese steel, etc., because the titanium is added for the purpose of cleansing and purifying the metal, and not with the expectation of producing new properties by its direct influence. On the contrary, when sufficient titanium has been added to produce a direct influence, the result has not always seemed favorable. Indeed, we may make excellent "titanium steel" in which not a trace of titanium can be found,—it having already performed its scavenging work and passed out of the bath together with the impurities it was commissioned to remove. The case is somewhat similar to that of manganese, which is added to almost all steels for the purpose of removing oxygen and sulphur, and neutralizing the effects of any traces of those elements which remain thereafter. Small doses of manganese are used for this purpose. However, when we wish to take advantage of the direct effect of manganese, we add some 15 per cent of the metal, and then get an entirely new result, which makes manganese alloy steel. Most of the titanium steel belongs in the first class, and not in the true alloy steel class. Indications are not wanting, however, that the direct effect of titanium on steel and

iron may have its advantages, and the future will perhaps see titanium alloy steel used for many purposes.

Even when used for cleansing purposes, titanium hardens, strengthens and toughens steel, and this seems to apply to crucible and even electric steel, as well as to Bessemer and open hearth. Touceda tested two steels in a Wright-Souther alternate testing machine: one of them had been treated with 0.25 per cent of the usual 10 per cent grade ferro-titanium alloy and the other steel was like it but without having been so treated. The untreated steel stood 2,676,000 revolutions at a maximum fibre stress of 38,872 lbs.; the treated steel stood 18,274,000 revolutions at a fibre stress of from 38,872 to 45,939 lbs. Waterhouse tested the segregation of steel which had been treated with titanium, and that which had not been so treated, and found a reduction in segregation in the former.

Titanium and Non-Ferrous Metals.

Titanium hardens and strengthens aluminum and increases its toughness and resiliency. It is stated that the addition of titanium, chromium and copper to aluminum gives some of the hardest and toughest light alloys yet produced. Some years ago small percentages of titanium were added to aluminum to make an alloy which was used by European bicycle manufacturers; the strength of the aluminum was increased from 23,300 to 73,500 lbs. per sq. in. Richards states that titanium has been alloyed with aluminum in proportions up to 7 per cent, but that 2 per cent gave the best result. This alloy had an elasticity comparable to spring brass, but it corroded badly and so has disappeared from the industrial world. Copper is greatly improved by the addition of titanium in small amounts to remove oxygen and gases, and this is a branch of the industry which is now undergoing rapid development.

Researches Upon the Effect of Titanium on Cast Iron.

Rossi added 5 per cent of a pig iron containing 0.20 per cent titanium to a non-titaniferous pig iron, and increased the transverse strength thereof from 3,390 to 3,778 lbs. per sq. in. Then he added 25 per cent of the same pig iron, but the strength was

increased only to 3,480 lbs. I am inclined to believe that he chilled his iron when using the larger amount of titaniferous pig, or else that he raised the freezing temperature without equally raising the casting temperature and thus destroyed in part the good effect on strength which the titanium treatment would have had. This matter of the casting temperature of cast iron is one which a great many investigators of titanium treatment seem to have overlooked; indeed, it is one upon which little scientific thought appears to have been expended, for I have found little published data upon it. However, Longmuir has studied the effect of casting temperature on tensile strength, and his figures will serve as a guide to show us the importance of this question: I have averaged the record of about forty-two tests published by him in 1903 and 1904, with the following result: The strength of iron cast at the correct temperature (estimated by Longmuir as about 1230° C. = 2246° F.) averaged 23,985 lbs. per sq. in.; that if iron cast too hot (estimated by him as about 1320° C. = 2408° F.) was 16,100 lbs., equivalent to a loss of 33 per cent; that if iron cast too cold (estimated as about 1120° C. = 2048° F.), was 17,781, or a loss of about 26 per cent. Therefore, if we are aiming to improve strength, we must guard against casting the iron either too hot or too cold, and this matter is equally important whether we operate by means of titanium or in any other way.

Rossi's experiments, which are quoted above, seem to have been made in crucibles and in the iron casting ladle. He supplemented them by others in which he used 4 per cent of a ferro-titanium alloy containing 10 to 15 per cent of Ti. By this means he increased the transverse strength of cast iron by 20 to 25 per cent, and the tensile strength by 30 to 50 per cent.

These tests were followed by those of Schiemann, who added 5 per cent of ferro-titanium thermit to a series of cast irons, and increased the tensile strength by varying proportions between 30 and 50 per cent.

Rossi reports another set of tests in 1905, in which he added 1 per cent of a ferro-titanium alloy containing 12 per cent titanium to cast iron and increased the transverse strength from 17 to 23 per cent, and the tensile strength from 6 to 29½ per cent.

In the same year, Goldschmidt reports a series of tests in which he added 0.1 per cent of titanium to iron by means of

thermit, and obtained increases in the transverse strength of from 1 to 17 per cent, and in the tensile strength of from 4 to 16 per cent.

In 1908, Prof. Martin Hokanson, of the Carnegie Technical Schools, found the compressive strength of chilled cast iron which had been treated with ferro-titanium alloy to be 298,000 lbs. per sq. in., as compared with 173,000 for the same metal untreated. The hardness of the treated metal was 557 (Brinell), as compared with 445 for the untreated iron.

Dr. Richard Moldenke made a series of tests on white and gray cast irons in 1908, with the following results:

TRANSVERSE TESTS OF WHITE AND GRAY CAST IRONS.
LBS. PER SQ. IN.

GRAY IRONS.			WHITE IRONS.	
Untreated iron	(aver. of 9 tests)	2,020	(Aver. of 8 tests)	2,050
Plus 0.05% Ti*	" " 4 "	3,100	" " 11 "	2,400
" 0.10% Ti	" " 3 "	3,030		
" 0.05% Ti	" " 6 "	3,070	" " 9 "	2,420
" 0.10% Ti	" " 6 "	2,990	" " 10 "	2,400
" 0.15% Ti	" " 4 "	3,190	" " 10 "	2,520

Average of treated gray cast iron, 3,070, equivalent to increase of 52 per cent; average of treated white cast iron, 2,430, equivalent to increase of 18 per cent.

Moldenke added ferro-titanium alloy equivalent to 0.10 per cent of titanium, to the bed of a cupola, but the result of tests of the metal therefrom was so irregular that he judged an average to be unrepresentative. I have duplicated this result several times, and am inclined to believe that the oxidizing influences brought to bear on the bed of a cupola make the use of titanium there of uncertain value as far as strength is concerned. The whole question of the use of titanium in the cupola requires investigation. The ferro-titanium alloy melts at a higher temperature than the iron itself, and therefore gets nearer the tuyeres before it begins to trickle down into the hearth. If, during this transit, it meets with slag, its value will be lost as far as the iron is concerned, because it will attack the oxygen in the slag and unite with it, thus being used up. Cupolas must be constantly drained clear

* Titanium added in form of ferro-titanium alloy.

of slag when titanium alloy is melted with cast iron therein. We must go even further than this precaution to prevent a layer of slag accumulating on top of the metal and intercepting the drops of melted alloy, because constantly draining the cupola will not keep the slag away, provided the level of the iron bath rises and falls several inches at intervals; as, for example, when the iron is collected inside the cupola instead of in the ladle.

Feise gives the following table of tests made on gray cast irons:

	Transverse Strength.	Deflection.
Without titanium	1230 kg/qcm	0.046 mkg
Plus 0.25% Ti.	1660 "*	0.056 "
" 0.50% Ti.	1410 "	0.053 "
" 1.00% Ti.	1340 "	0.066 "

These results corroborate the observations of others: that the maximum effect on strength appears to be obtained with 0.10 per cent or so of titanium.

The most unsatisfactory results I have found were published by Treuheit, and report an elaborate series of tests on cast iron treated with ferro-titanium thermit and ferro-titanium alloy alternately. The temperatures were measured by a pyrometer and the resulting metal was tested both by tensile and transverse methods. In some cases the treated metal was weaker than that which had not been treated, and sometimes a little stronger, but never enough different to indicate anything especially interesting. In examining the record of this work, one does not have to look far to find a reason for the unsatisfactory result: The temperatures at which the iron was cast were widely variant, sometimes being above 1300° C. (2392° F.), which is shown by the work of Longmuir to be detrimental to quality. One might also infer from the author's words that he did not allow the metal to stand long enough after adding the titanium, so that the latter could exert its cleansing influence; at best, his record is not clear on this point. Three minutes should be allowed the titanium to act upon cast iron before it is teemed, and more if the alloy is not then absorbed, as indicated by the pasty state of what remains. If the iron has not heat enough to permit this three-minute wait

* Equivalent to 35 per cent increase in strength.

then it should have been produced in hotter condition in the first instance, but, in any event, if it cannot be held three minutes and still poured at the correct teeming temperature, one must not blame the lack of success on the treatment, but on the manner in which the treatment is performed. I have failed in test after test because the metal had to be carried some distance from the cupola before it could be treated, or because it was about the correct pouring temperature before the three-minute wait, and therefore too cold thereafter. If this paper proves that the titanium treatment is advantageous to cast iron, then it must also prove that it is advantageous to perform the treatment properly.

When titanium unites with the oxygen or nitrogen in iron or steel, there is unquestionably an evolution of heat which opposes the cooling of the bath during the wait. Fitzgerald showed that a bath of cast iron increased 25° F. during its treatment with 1 per cent of titanium in the form of ferro-titanium, but that this lasted only one minute and then the temperature slowly fell again. The original temperature of our metal must be hot enough to endure this drop and still be at the correct point.

Another mistake made by Treuheit, when treating his iron with ferro-titanium alloy, was heating his alloy red hot in the ladle before tapping the iron therein. This heating has the effect of oxidizing the alloy and reducing, or maybe nullifying, its cleansing effect; the action was once recommended by the manufacturers of the alloy, but is now abandoned. Furthermore, the alloy should not be placed in the bottom of a ladle because its infusibility causes it to become pasty and stick to the lining without dissolving in the bath. It should be thrown into the ladle after there is a layer of iron upon which it can float, and then the in-pouring stream of metal will stir it well and assist its absorption.

If Treuheit's experiments were the only ones to guide us, or if they were confirmed by other results skilfully obtained, then we might doubt the value of titanium to cast iron, but the many favorable researches quoted herewith would make us question Treuheit's conclusions even if we could not point out very definitely the cause of his ill-success.

C. H. Gale, one of the most experienced American malleable cast iron manufacturers, reported in 1911 the results of many tests made on the treatment of malleable cast iron with ferro-titanium

alloy. In his first test, Gale added, first 1.25 per cent, and then 2.50 per cent of the alloy in the ladle, with the consequence that the iron was teemed much too cold, and also it proved to be mottled instead of having the usual, and desired, white fracture. Both of these conditions would, of course, decrease the strength of the metal; nevertheless, the treated bars in one set averaged slightly stronger than those untreated, and, in another set, were about 19 per cent weaker in tensile test. The transverse tests of the treated metal proved it to be from 5 to 30 per cent stronger than the untreated metal. Nevertheless, the result indicated that such a ladle treatment of malleable cast iron did not promise much success unless the silicon were reduced so as to prevent mottled iron being produced, since titanium causes a precipitation of graphite, and unless the metal were increased in temperature so as to wait during the time of treatment and still be at a good heat for pouring. I may say here that a test which I made on malleable cast iron fully corroborates this conclusion.

Gale then made a series of tests adding the alloy in the furnace about 30 to 45 minutes before tapping, but it scarcely seems likely that this would have as marked a result as if the alloy had been put in the furnace as soon before tapping as practicable, because titanium oxidizes so quickly that its effect would be lost in a comparatively short time. However, the transverse shows an improvement on the average of 15 per cent in the bars treated with 0.30 per cent of the alloy, and 17 per cent in the bars treated with 0.60 per cent. The tensile tests were not so favorable: 12 per cent and $\frac{1}{6}$ per cent respectively,—but Gale cautions us against taking the tensile tests too seriously because the bars were round in section and may not have been sound. In the discussion of these results, W. D. Alexander gave the report of a long series of tests made by him upon the treatment of malleable cast iron with the usual ferro-titanium alloy, *i. e.*, that containing from 10 to 15 per cent titanium,—in proportions from 0.47 to 1.75 per cent. He added the alloy in the hand ladle caught from the furnace, and thus there was a great cooling of the metal, especially when using the larger amounts of alloy. The ductility of the metal was then tested, after annealing, by upsetting bars with a ten-pound sledge. The metal treated with 0.47 per cent alloy showed an increase in ductility by this test of 105.3 per cent; that treated

with 0.75 per cent alloy improved 65.7 per cent; that with 1 per cent alloy decreased 10.5 per cent; that with 1.25 per cent decreased 69.1 per cent; that with 1.50 per cent alloy decreased 59.4 per cent, and that with 1.75 per cent decreased 128.2 per cent. Evidently the best result would be obtained with 0.47 per cent alloy or less, unless some means could be had of heating the metal hotter before the treatment.

In 1911 Geiger published his book on iron and steel foundry practice, in which he devotes two sections to the effect of titanium on the ferrous metals. Finally, he reports a series of tests on iron with titanium in proportions of 0.04, 0.07 and 0.10 per cent,—equivalent to 0.40, 0.70 and 1.00 per cent of the usual ferro-titanium alloy, respectively. The respective improvements in tensile strength were 12, 24 and 26 per cent; of transverse strength, 6, 9 and 10 per cent, and of deflection in transverse test, 9, 11 and 6 per cent.

Thomas D. West, by adding 12 ozs. of the usual ferro-titanium alloy to a ladle of cast iron containing 225 lbs., obtained an increase of 27 per cent in the transverse strength, as an average of five tests; by adding 22 ozs. of ferro-titanium alloy to 225 lbs. of iron, he obtained an increase in transverse strength of 32 per cent, as an average of five tests.

Osann reports in his new book on the improvement in the compressive strength of cast iron for car wheels: In one case an increase of 18 per cent obtained by treatment with titanium, and, in another case, of 75 per cent.

This brings me to my own tests, which included both white and gray cast iron. The iron was melted in a cupola (except for one test on malleable cast iron, referred to on page 318), and cast into round bars 18 in. long and from 1 in. to 1.3 in. in diameter. They were tested transversely on supports 12 in. apart, as per the standard testing specifications of the American Society for Testing Materials and the American Foundrymen's Association. The figures reported below indicate moduli of rupture in lbs. per sq. in. During the research I made several errors in operation, due to ignorance of the conditions which should have prevailed, but the reports of these improperly performed tests are here given with the others, because, if they teach nothing useful, they at least emphasize the need of performing the titanium

treatment correctly. The treatment was made with the usual ferro-titanium alloy containing from 10 to 15 per cent titanium, and the additions are recorded in percentages of alloy added, instead of percentages of titanium.

Considering first some of the incorrectly performed tests: I made two tests charging the alloy with the iron of the bed of the cupola, hoping that the deoxidizing effect of the titanium would overcome the oxidizing effect of the blast. This hope was not realized, as will be seen below:

TEST No. 1 (CUPOLA BED).

Iron without titanium (average of 4 tests)..........	42,175 lbs.	
Iron with ½% alloy on bed (average of 4 tests)......	40,493 lbs.	decrease 4%

This failure of the titanium-treated iron to exceed in strength that not treated is the more significant because the same iron showed an increase of 6 per cent strength when ½ per cent alloy was added in the ladle, although it had to be carried some distance in the foundry before pouring, and was therefore too cold after the treatment. The untreated iron was not bed iron and this difference is important.

TEST No. 2 (CUPOLA BED).

Iron without titanium (average of 4 tests).........	41,520	
Iron with 0.40% alloy on bed (average of 4 tests)...	40,610	decrease of 2%

In spite of the apparent decrease in the treated metal, the titanium is shown to have been beneficial, because normally bed iron would have been 20 to 30 per cent weaker than the other.

This same iron gave an increase in strength of 16 per cent when treated with ½ per cent alloy in the ladle, and of 9 per cent when treated with 2 per cent alloy in the ladle.

I tried the experiment of adding the alloy in a cupola from which the slag was not drained continuously. The results were irregular and inconclusive, as shown below:

TESTS No. 3, 4, 5 AND 6 (WASTED IN CUPOLA SLAG).

Iron without titanium (average, 4 tests)............	42,378	
Iron with ½% alloy (average, 4 tests)...............	35,775,	decrease of 15%

Iron without titanium (average, 6 tests)............ 48,517
Iron with ½% alloy (average, 6 tests)............... 54,830, increase of 13%

Iron without titanium (average, 8 tests)............ 44,893
Iron with ½% alloy (average, 8 tests)............... 42,856, decrease of 5%

Iron without titanium (average, 2 tests)............ 55,280
Iron with ½% alloy (average, 2 tests)............... 52,570, decrease 5%

Several tests were made on iron which had to be carried some distance while molten, and which before treatment was at a good temperature for teeming, but cooled too far during the three-minute wait so that it was too cold after treatment. At first the treatment was performed in a ladle holding about 225 lbs. in which the heat lost by radiation was very large. The results follow:

TEST NO. 7 (IRON TOO COLD).

Iron containing 2% Si; 0.075% S; 0.73% P.; 0.57% Mn.

Iron without titanium (average, 2 tests).............. 55,280
Iron with ½% alloy in ladle (average, 2 tests).......... 50,100 decrease 10%

TEST NO. 8 (IRON TOO COLD).

Iron containing 1.25% Si.; 0.040% S.; 0.20% P.; 0.70% Mn.

Iron without titanium (average, 3 tests).............. 49,730
Iron with ¼% alloy in ladle (average, 4 tests).......... 44,680 decrease 10%
Iron with ½% alloy in ladle (average, 2 tests).......... 46,000 decrease 8%
Iron with 1% alloy in ladle (1 test only).............. 54,300 increase 9%
Iron with 2% alloy in ladle (1 test only).............. 47,850 decrease 4%

If the metal had been poured as cold as this, and had not been treated, the decrease in strength would have been fully 25 or 30 per cent (see Longmuir, *ante*).

After this the iron was treated in a one-ton ladle, in order to reduce radiation of heat, but still the metal was cool after the three-minute wait, and the results were only partially satisfactory.

TEST NO. 9 (IRON COOL).

Iron containing 1.50% Si.; 0.75% P.

Iron without titanium (average, 6 tests).............. 48,517
Iron with ½% alloy in ladle (average, 5 tests).......... 49,280 increase 2%

Test No. 10 (Iron Cool).

Iron containing 1.30% Si.; 0.37% P.

Iron without titanium (average, 8 tests)..............	44,893	
Iron with ½% alloy in ladle (average, 7 tests)..........	48,419 increase	8%

Test No. 11 (Iron Cool).

Iron containing 0.90% Si.; 0.20% P.

Iron without titanium (average, 5 tests)..............	42,175	
Iron with ½% alloy in ladle (average, 3 tests)..........	44,525 increase	6%

Using iron which could be treated and poured without intervening delays, except, of course, the three-minute wait for treatment, the following results were shown:

Test No. 12.

Close-grained, gray iron, over 1% P.

Iron without titanium (average, 4 tests)..............	35,810	
Iron with 0.20% alloy in ladle (average, 4 tests).......	39,640 increase	11%
Iron with 0.64% alloy in ladle (average, 4 tests).......	40,545 increase	13%

Had I thought in time to make such arrangements that both treated and untreated iron should be poured at exactly the same temperature, the test would have been still more representative. As it was, the treated iron was poured a little cooler than the other.

Test No. 13.

Gray Iron.

Iron without titanium (average, 4 tests)..............	41,520	
Iron with ½% alloy in ladle (average, 4 tests)..........	48,350 increase	16%
Iron with 2% alloy in ladle (average, 7 tests)..........	45,390 increase	9%

Test No. 14.

White Iron.

Iron without titanium (average, 2 tests)..............	32,800	
Iron with ½% alloy in ladle (average, 2 tests)..........	37,450 increase	14%

Two tests were made by adding the alloy in the cupola, the slag being continuously drained:

TEST No. 15.

White Iron.

Iron without titanium (average, 2 tests)	32,800
Iron with 0.3% alloy in cupola (average, 8 tests)	47,040 increase 43%
Iron with 0.45% alloy in cupola (1 test only)	37,600 increase 15%
Iron with 0.60% alloy in cupola (1 test only)	32,950* increase ½%

Three tests were then made on iron containing between 3 and 4 per cent of phosphorus, with the following results: The iron was liquid when poured, but not very hot.

TESTS NOS. 16, 17 AND 18 (HIGH PHOSPHORUS).

Iron without titanium (average, 3 tests)	46,583
Iron with 0.37% alloy in ladle (average, 2 tests)	49,900 increase 7%
Iron without titanium (average, 2 tests)	47,600
Iron with ½% alloy in ladle (1 test only)	54,650 increase 14%
Iron without titanium	42,450
Iron with 1% alloy in ladle (average, 2 tests)	46,385 increase 10%

Iron containing about 9 per cent phosphorus was tested:

TEST No. 19 (VERY HIGH PHOSPHORUS).

Iron without titanium (average, 2 tests)	41,900
Iron with ½% alloy in ladle (average, 2 tests)	42,630 increase 2%

The significance of these results is: that iron may be increased in strength as much as 43 per cent by the correct use of titanium; but, to accomplish the best results, the titanium must not only be in correct proportions, but the iron must be given a fair chance by allowing the titanium a full opportunity to become thoroughly dissolved in it (*not less than three minutes' treatment*), so that it is neither wasted in the slag nor left unmelted in the ladle, and by ensuring that the iron is poured neither too hot nor too cold.

* Last charge in cupola; iron badly oxidized.

We may summarize the results obtained by different investigators as follows:

	Used.	Increased.	
	Ferro-titanium.	Tensile Strength.	Transverse Strength.
Rossi	Alloy	30 to 50%	20 to 25%
Schiemann	Thermit	30 to 50%	
Rossi	Alloy	6 to 30%	17 to 23%
Goldschmidt	Thermit	4 to 16%	1 to 17%
Moldenke	Alloy		18% (white)
Moldenke	Alloy		52% (gray)
Guillier			49% (mall. iron)
Guillier			14 to 30% (gray)
Feise	Alloy		35%
Treuheit	Thermit and alloy	No important† change	No important† change
Gale	Alloy		10 to 20%*
Alexander	Alloy	Increased	Ductility*
Geiger	Alloy	12 to 26%	6 to 10%
West	Alloy		27 to 32%
Stoughton	Alloy		10 to 43%*

These results indicate that it is entirely possible, by correct treatment with ferro-titanium alloy, to increase the strength of cast iron from 30 to 50 per cent. If this can be done part of the time, then it only remains to determine the correct conditions in order to attain equal success all the time. Some of these conditions I have pointed out in the foregoing pages, but do not consider that the problem is completely solved as yet. What has been learned is published now in the hope that it will inure to the benefit of makers and users of cast iron.

* When treatment was properly performed; otherwise, results different and variable.
† Treatment not made correctly.

DISCUSSION ON MR. BRADLEY STOUGHTON'S PAPER ON "THE CLEANSING EFFECT OF TITANIUM ON CAST IRON."

Mr. Stoughton.—Titanium is used, as you know, very largely for steel. It is estimated that nearly a million tons of steel will be treated by titanium this year. It has the effect of increasing the strength and hardness of steel and it is therefore used largely for railroad rails. Probably half a million tons a year of railroad rails are now treated with titanium. Titanium is also used to some extent for treating non-ferrous metals; it hardens and strengthens aluminum and increases its resiliency a good deal, and its effect on copper is much more marked, hence it is undergoing rapid development in the copper industry.

The Secretary.—One point in connection with the tests made has always seemed a little hazy to me. Pouring test pieces from ladles of the same iron treated and untreated with titanium alloy must leave a considerable difference in temperature between the two. Why not, when adding the alloy to one ladle, add an equal weight of scrap iron to the other, so that both may cool about the same, and the results be more comparable.

Mr. Stoughton.—That would indeed be an improvement.

Mr. Neill.—I have never used the alloy successfully in the ladle. I think it was Dr. Moldenke who advised me to use it while we were out in Toronto at the Convention there. We took hold and used it to strengthen our rolls, and when we used it in the ladle, the strength of the rolls was not materially improved. But I was subsequently advised to try it on in cupola charges and our rolls became considerably stronger. In casting rolls, we all know that we have to have the iron down to a certain temperature. I don't believe that at this temperature the titanium will make any difference for it will not melt or mix with the iron. In regard to coming in contact with the slag, I may say that I have no slag-hole in my cupola. The cupola is one hundred years old and it is constructed in such a manner that we cannot get

any slag-hole into it. I am therefore obligated to do the best I can. It is hard going and tries my patience lots of times, but I would like to get all the strength I can out of titanium, because I believe it is a great thing and I would like to hear if any of the members have ever used it for making chilled rolls. Another thing I would like to ask is if it has any cleansing effect on the iron?

The Secretary.—They evidently seemed to make good cupolas a hundred years ago.

Mr. Stoughton.—I did not mean to give the impression that titanium produced a bad effect in the cupola, but that it did not do any good if it got into the slag. I discovered that in my test and others had discovered it also, as did Dr. Moldenke; but when the conditions are all right, I think it is a very good thing in the cupola, and I got the best tests of all when I put it in the cupola and constantly drained off the slag and got it out of the way. If Mr. Neill can get it into the iron in the cupola I think it is better than getting it in the slag, but the difficulty I found was that it would get into the slag. In regard to cleansing the iron, I will say that I found this to be very marked in every case. Where the iron is dirty it will bring this dirt out. While I cannot say from my own tests, but from the tests of others, it appears that titanium also brings the sulphur up and out a little bit. Goldschmidt and Treuheit, in their experiments, and one other, found the sulphur was brought to the surface as well as the dirt and slag. It is this effect of bringing the dirt and slag up that is the chief reason why it is used for steel. It prevents the shelling off of railroad rails when there are little specks of slag and manganese sulphide in them, and its influence in cleansing the iron is one of its important effects on that metal.

Mr. West.—Unfortunately, I was not able to hear all of Mr. Stoughton's paper, but I believe I heard something with reference to some of my own tests?

Mr. Stoughton.—Yes, Mr. West.

Mr. West.—About eight months or so ago, I ended quite a series of experiments with vanadium and titanium in car wheel iron. Probably most of you read the results of those tests, but I chiefly want to emphasize my disappointment in not finding a greater uniformity in the results. The tests were made under

conditions which were as uniform as it was practicable to have them. With regard to the matter of the manipulation of the mold, as well as the temperature of the metals as found, as far as I could judge, the conditions were as nearly uniform as practicable. It was but natural that with the different amounts of vanadium and titanium that were placed in the ladles of metal that there would be differences observable in the color and action of the molten metal while the alloys were being absorbed by it. The metal with the titanium in it would show a beautiful, broken surface, radically different from that of the original metal. The metal with the vanadium in would show a rich silver color. But in both cases you could feel that there was a reaction going on. Now, in some cases, I obtained additional strength by the use of both those alloys, and in other cases I did not. I hope in the near future to again make some experiments along the same lines, and to carry out some thoughts I have in this connection to see if it is possible to get uniformity in results. It is certainly the case with any alloy, that if we cannot on every occasion get the results we should have, it is practically useless to us. We have no confidence in it.

I will close these remarks by saying that I believe there is considerable more to be done along this line yet to make it satisfactory for cast iron. In steel, I don't think there is any question as to the value.

Mr. Hall.—I would like to ask a few questions: first, what was the nature of the iron Mr. Stoughton used in his experiment? Was it an all-pig or a scrap mixture? In other words, what was the quality of the iron treated? And second, if he considers that all iron will be benefited by an addition of titanium? That is, provided it is a good, clean, all-pig hot iron in the first place. Or does he consider that it is only the iron that is a little off-color that can be improved by the cleansing action of titanium. Finally, does the titanium act through its alloying with the iron or simply by its removal of impurities?

Mr. Stoughton.—I would like to say, first, lest I be misunderstood, that when I quoted Mr. West as getting first 27 per cent and then 22 per cent increase in strength and did not quote any case of his failing to get any improvement, I may say that I did not know that he had made any tests in which he had failed to get

an improvement. I would not have quoted any one in favor of something and at the same time kept quiet about his not having gotten good results if I had known it. This much I ought to say for my own protection. In regard to Mr. Hall's question—the irons used were some of them pig and some scrap. It was good scrap, however, that is, the return scrap from the foundry. The metal was good machinery iron and I have the analyses. Some were Bessemer iron used for machinery work and some were high phosphorous iron. Most of the high grade pig-irons would run about .2 per cent, .3 per cent or .4 per cent phosphorus, and then some of the other iron would run .7 per cent. The Bessemer iron, of course, would run quite low in phosphorus. It didn't seem to make any particular difference in the result whether the irons were good or were bad. Then I tried some tests on sash weights. You know what quality of iron that is, and some of the sash weights ran up to nearly 2 per cent phosphorus. They were made by melting bundle steel scrap with 10 per cent of grate bars and other bad material mixed in with them, and some of these irons were increased 15 per cent in strength by the treatment. We did not notice any particular difference in the irons, whether they were high or low quality, except the irons containing .9 per cent of phosphorus, which did seem to be increased by a very small amount.

In regard to whether titanium acts by alloying or not—it is my belief that it acts altogether by cleansing the iron and that the alloying effect is practically nil. You understand when you use ten points of the titanium alloy, not titanium, to a ton of iron, there cannot be much effect from that tenth of one pound of titanium in a ton of iron, as regards its direct alloying influence; it must be, if at all, in its cleansing effect. That is the conclusion I came to in this study.

Mr. Slocum.—Mr. Stoughton spoke about the name titanium had in the early days before we knew much about it and compared it to "the dog that had a bad name." I have been chasing that dog for five years and think we have got him pretty well down to his last legs. In the five years in which this alloy has been made, it has not been possible to learn all about the element which the scientists tell us gives a powerful reaction in steel; probably a less powerful one in iron, and gives a special benefit in the wearing

qualities of both. The small percentages which are recommended for foundry use, which are from .1 per cent up to .3 per cent or .4 per cent of alloy, not of titanium, cannot possibly add tremendously to the strength of a metal, because there is not enough of this material used. I, personally, saw a ladle of iron, treated with titanium alloy, held 28 minutes until the melter said it was down to the normal pouring temperature and that when he could give that length of time or even 10 minutes to the holding, he invariably got the good castings that he desired. Now, in order to hold iron for some time until it is down to a normal temperature, it must first be hotter than normal; consequently, in using an alloy of this kind, it is desirable to get, if you can, very hot metal and then hold it.

As Mr. Stoughton has very ably said, titanium has an affinity for slag. If you put this material into your ladle and let it touch the slag, you can see it with the naked eye jump for those impurities which are already on the surface and which, therefore, need no attention. It is absolutely necessary to incorporate the alloy in the molten metal in such a manner that the alloy strikes the metal which has been at least partially cleansed and enables it to remove the impurities remaining in the iron or in the steel. Titanium is added, in practice in the majority of cases, in the ladle. In crucible melting practice, it may be added in the crucible and melted down with the charge. Good results have been obtained in this way; but in iron, in which the interest seems to be principally this morning, I would like to say that low silicon irons, such as I believe are generally used in making rolls are benefited by a particularly small percentage of alloy. If you will try these small percentages in irons of which rolls are made and which are very similar to car-wheel irons, you will find that 1/10 of 1 per cent in two or three tons will have a materially beneficial effect, while ½ of 1 per cent and 1 per cent and the higher percentages will be of no use at all. The use of titanium, as I apprehend, in removing impurities, almost necessarily makes the metal more dense. This density is particularly desirable in rolls. It gives you a wearing quality without which a great many rolls would be useless. They go into, I think, probably the most severe service of any kind, and the consistent usage of and demand for titanium leads me to believe that in chilled rolls it is almost

infallible. But the metal must be hot. I do not recommend that titanium is a cure-all for foundry practice. If you find that, after having added the alloy to the metal, it rises to the surface and when it is stirred in, it does not dissolve, the metal was too dull for the alloy. If it dissolves and the metal is held as suggested by Mr. Stoughton, I think it invariably follows that beneficial results are secured. In conclusion, I have only to suggest that anyone desiring to try it, begin with a small percentage and not a large one and only work up to the point where the benefit remains.

Mr. Bole.—I would like to add a word or two. I made some experiments a year ago at Trafford City with titanium. In order to cut out the disturbing effect of irregularities in metals, I prepared a 40-ton heat of metal in the air-furnace so as to bring down a perfectly uniform metal to experiment with. Then I ran three days in the cupola melting that stock, adding titanium in the cupola; and ran three days the very same stock without the addition of titanium. I thought we had achieved the refinement of tests in that way, because a man might use iron from the same furnace one day and the second day take that same brand of iron from the furnace and find variations in the metal. We started off with the purest metal that could possibly be procured, perfectly uniform, and to note the results of the tests, we poured four test bars from every ton of the metal. After carefully breaking the test bars and tabulating the results, we found that the difference between the strength of the untreated iron and the strength of the treated iron was so small as to be absolutely negligible. That seems to indicate that if your iron was first-class to begin with, it did not need the addition of titanium and that the titanium would not do it much good; but after we had concluded these tests, I gathered up all the bad stock we had around the yard, which we had only sold to the scrap iron man and which we don't use ourselves at all, and ran it down in a heat, adding a large quantity of ferro-titanium, and was rather surprised at the good effect obtained. In that way, we were able to make automobile fly-wheels and other castings that were quite satisfactory, out of stock that was in my opinion, absolutely unfit to use otherwise.

The Secretary.—That is the sum and substance of my own experience. If you have got bad material, titanium fixes it up; if you have got good material, it doesn't.

Mr. Slocum.—I recall an experiment made last year at the Westinghouse Machine Company, where they took grate bars, burnt iron, etc.—there wasn't a pound of good iron used—and added $\frac{1}{4}$ of 1 per cent of the titanium alloy and $\frac{1}{4}$ of 1 per cent of ferro-manganese and from that poured ten test bars, all of which were perfect. They had an average of 3,500 pounds from the ten bars, with a minimum of 2,865 pounds, if I remember the figures correctly. This goes to show that to make a good, uniform iron out of pretty poor material, it can be done with titanium. Nevertheless, there are a few things that must be taken care of. You cannot get results from titanium if it is added so that it comes in connection with the slag. You cannot get results if your iron is too hot; it must be held quiet until it is down to a normal temperature. You will not get it as an economical result if you add too considerable a percentage, which makes the cost equal that of good irons. In good irons, the chief aim would be not so much to get an increase in strength, because, after you get up to a certain point, these small percentages will not give an increased benefit. But they will give a uniform smooth casting, one that is easily machined and one that, if it has to go into service for wear, will outlast the plain or the untreated casting anywhere from 50 per cent upward.

STANDARD SPECIFICATIONS FOR STEEL CASTINGS.

Adopted by the American Society for Testing Materials June 1, 1912.

(Reprinted by courtesy of that Association.)

CLASSES.

1. These specifications cover two classes of castings, namely:

Class A, ordinary castings for which no physical requirements are specified.

Class B, castings for which physical requirements are specified. These are of three grades: hard, medium, and soft.

PATTERNS.

2. (*a*) Patterns shall be made so that sufficient finish is allowed to provide for all variations in shrinkage.

(*b*) Patterns shall be painted three colors to represent metal, cores, and finished surfaces. It is recommended that core prints shall be painted black and finished surfaces red.

I. Manufacture.

PROCESS.

3. The steel may be made by the open-hearth, crucible, or by any other approved process.

HEAT TREATMENT.

4. (*a*) Class A castings need not be annealed unless so specified.

(*b*) Class B castings shall be allowed to become cold; shall then be reheated to the proper temperature to refine the grain and allowed to cool slowly.

II. Chemical Properties and Tests.

CHEMICAL COMPOSITION.

5. The steel shall conform to the following requirements as to chemical composition:

	Class A.	Class B.
Carbon.........	not over 0.30 per cent	....
Phosphorus.....	" " 0.08 "	not over 0.05 per cent
Sulphur.........	....	" " 0.05 "

LADLE ANALYSES.

6. To determine whether the material conforms to the requirements specified in Section 5, an analysis shall be made by the manufacturer from a test ingot taken during the pouring of each melt. Drillings for analysis shall be taken not less than $\frac{1}{4}$ in. beneath the surface of the test ingot. A copy of this analysis shall be given to the purchaser or his representative.

CHECK ANALYSES.

7. A check analysis of Class B castings may be made by the purchaser from a broken tension or bend test specimen, in which case an excess of 20 per cent above the requirements as to phosphorus and sulphur specified in Section 5 shall be allowed. Drillings for analysis shall be taken not less than $\frac{1}{4}$ in. beneath the surface.

III. Physical Properties and Tests.

TENSION TESTS.

8. (*a*) The steel for each grade of Class B castings shall conform to the following minimum requirements as to tensile properties:

	Hard	Medium	Soft
Tensile strength, lb. per sq. in...	80 000	70 000	60 000
Yield point, " " ..	36 000	31 500	27 000
Elongation in 2 in., per cent.....	15	18	22
Reduction of area, "	20	25	30

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

BEND TESTS.

9. The test specimen for soft castings shall bend cold through 120 deg. and for medium castings through 90 deg., around a 1-in. pin, without fracture on the outside of the bent portion.

ALTERNATIVE TESTS TO DESTRUCTION.

10. In the case of small or unimportant castings, a test to destruction on three castings from a lot may be substituted for the tension and bend tests. . This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from the same melt, annealed in the same furnace charge.

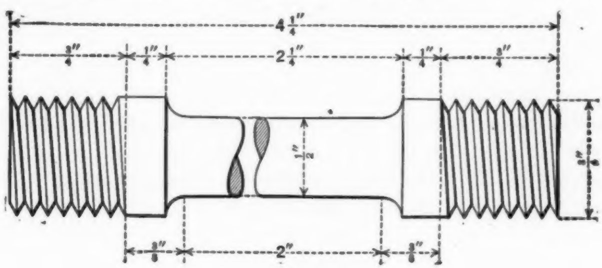


FIG. 1.

TEST SPECIMENS.

11. (*a*) Test bars shall be attached to Class B castings weighing 500 lb. or over, provided the design of the castings will permit. If the castings weigh less than 500 lb., or are of such a nature that test bars cannot be attached, two test bars shall be cast to represent each melt; or the quality of the castings shall be determined by tests to destruction as specified in Section 10. All test bars shall be annealed with the castings they represent.

The manufacturer and purchaser shall agree whether test bars can be attached to castings, and also on the location of the bars on the castings and the method of casting unattached bars.

(*b*) Tension test specimens shall be of the form and dimensions shown in Fig. 1.

Bend test specimens shall be 1 by ½ in. in section.

NUMBER OF TESTS.

12. (*a*) One tension and one bend test shall be made from each melt.

(*b*) If any test specimen shows defective machining or develops flaws, or if a tension test specimen breaks outside the gage length, it may be discarded; and the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

IV. Workmanship and Finish.

WORKMANSHIP.

13. The castings shall substantially conform to the sizes and shapes of the patterns, and shall be made in a workmanlike manner.

FINISH.

14. (*a*) The castings shall be free from all injurious defects.

(*b*) The castings offered for inspection shall not be painted or covered with any substance that will hide defects, nor rusted to such an extent as to hide defects.

V. Inspection and Rejection.

INSPECTION.

15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

REJECTION.

16. Castings which show injurious defects before or after machining will be rejected, and the manufacturer shall be notified.

ARC WELDING.

By J. F. Lincoln, Cleveland, Ohio.

The welding of metals by the use of the electric arc dates back to the experiments of Dr. Bernardo prior to 1892. He first successfully used the electric arc for the melting of metals so as to join them together as a weld. After these successful experiments, which were laboratory experiments in every way, arc welding was never used commercially for a good many years, the chief reason being that difficulties which would arise, supposedly of a chemical nature and therefore insurmountable, were really the results of clumsy handling. Within the last three or four years, however, adaptation of the electric arc to the welding of metals has become prominent and is becoming increasingly so.

Like all new processes, the results from it are still clouded with a great deal of humbug which the pioneers wish to cast around a new process so as to keep other people out of it. We see this same attitude being taken by a great many people who are the originators or developers of a new experiment which, when reduced to its lowest terms, has nothing mysterious about it.

The electric welding of metals, or the welding of metals by any other process, depends upon heating of the two pieces which are to be welded to a welding temperature, and then putting them together at that temperature, applying pressure if possible. It makes no difference whether the metals are heated by an arc, by oxy-acetylene, by the blacksmith forge, blast furnace or any other process, the results are the same. If they are put together at the welding temperature, they will stick together, provided the faces applied are clean. We see this same result in the pouring of pig iron. The molten metal will become one solid piece even if it is poured into the mold at several distinct periods. However, if the metal becomes chilled the weld will become imperfect, and instead of having a true weld, the piece will merely stick together in a weld very easily broken. This is the real difficulty

in getting an efficient weld with the arc. In some spots the filler and weld are not put together at a welding temperature and a true weld does not result.

Reduced to its simplest terms, an arc welder is a transforming device for changing current at a high voltage or of a kind which is not applicable to the electric arc to current which is easily applied to the electric arc. All arc welders do this more or less satisfactorily and none do anything more.

The changing of the current which is necessary for the best application of the arc is first the reduction of the voltage to a value somewhere between 30 and 60 and then some kind of an arrangement so that this voltage will be reduced as the current increases. In other words, as the resistance of the arc decreases on account of increasing current, the amount of current that flows must not increase to a point which will burn the weld or give varying results. That is, the welder must have a dropping characteristic so that as the current flow increases the voltage will drop, and drop considerably.

The first types of arc welder were of resistance units, either a water rheostat or grid resistance which placed sufficient resistance in the circuit so as to reduce the voltage to the proper point for use in the arc. This is a very satisfactory method for arc welding and the only disadvantage to it is that about 65 per cent of a 110-volt current and 85 per cent of a 220-volt current is wasted in the resistance. Another bad feature is the fact that it is rather difficult to handle large currents through resistance in a satisfactory manner on account of the burning out of the resistance units.

The second form which was put on the market was a motor generator set, the only possible advantage of which over the resistance method being some current saving. There are many devices of this kind which give a satisfactory arc and save some of the current which was lost in the resistance before. It is necessary with this to keep a considerable amount of resistance in circuit in order to act as a ballast, or to limit the amount of current when only a small amount is required.

Another bad feature of such a set is the fact that when no weld is being made the motor generator set as a general thing is kept in operation with its constant loss. The cost of a set of this

kind is also high, and for these reasons they are not often used. On account of these inefficient methods of transformation, the welding by oxy-acetylene jet process has come into considerable favor. This welding is done by the union of a jet of oxygen and acetylene gas which gives an extremely hot flame. It is, however, impossible to get a large flame of great heat from the oxy-acetylene process on account of the impossibility of using it satisfactorily and directing the heat where needed. Another great disadvantage of the oxy-acetylene gas process is its great operating cost. In other words, heat can be furnished at the weld for about five per cent of the cost with the arc welder over the oxy-acetylene welder. This is taking oxy-acetylene at the market value and the current at a two-cent rate. On account of this it is self-evident that unless some great advantage can be gained from the use of oxy-acetylene that it is doomed to failure on account of its high cost in competition with the arc. It has no advantage over the arc in any way, since it cannot be directed any more easily than the arc and the heat cannot be regulated from it with any greater ease. It also has a very great disadvantage in that it will not produce good results on a large weld on account of the heat conductivity of the metals. Heat will be so rapidly dissipated from a weld by the metal itself that the metal in the weld cannot be kept at a welding temperature, so that a weld of this kind is very apt to be full of particles of metal which are not really welded. Another disadvantage is that the jet, when used in a deep hole, will melt off the metal parts of the burner. For this reason the oxy-acetylene process is practically limited to welds where the application is easy and the work to be done is small.

The arc welder made by the Lincoln Electric Company is a single machine which in appearance resembles the generator of about the same capacity. It has in its simplest form a single commutator and five brushes. No resistance is used in any part of the welder, or for its control, thus very materially assisting in keeping it simple. The controlling panel has four controlling switches, which by changing the connections in the welder fields varies the amount of current in the arc and the voltage at the arc. All current variations are automatic and by a combination of the switch controlled connections, and by varying the length

of the arc, a continuous and unbroken line of current values can be gotten at the arc from the maximum capacity of the machine to a very small part of the full current rating.

This arc welder also can be short circuited without harm and without taking a current from the line which is in any way harmful. In fact, the short circuit power is much less than full load power. This machine operates under all conditions without any sparking or injurious heating.

The efficiency of this welder is the one point in which it excels all other methods now in the market. It will do the same work with not to exceed 60 per cent of the power that is required with any other method that is known. This high efficiency is on account of the entire elimination of all resistance or other losses other than the losses in the single machine itself.

The principle of operation is as follows: On a motor with an armature with the usual wave winding is superimposed a series field on interpoles between the main poles. This series field is variable by taking various taps out of it which make it easily changeable. An arc brush is placed between the main brushes from which the arc current is taken. The field which generates this arc current as shown above is weakened by the arc current flowing in the series coils. By varying the resistance of the arc, by changing its length or by changing the number of turns in the series field, the control is obtained.

The usual application of the electric arc in welding is made by forming an arc between a carbon electrode and the piece to be welded. Since the piece which is welded is the positive electrode practically all the heat of the arc is liberated here, very little being released at the negative carbon electrode. Into this arc is passed the filling metal which rapidly melts off and drops onto the positive electrode kept at a welding temperature by the arc. In this way a weld which is perfect can be made because both the filler and the piece to be welded can be kept at a temperature at which the metal is fluid. Ninety-five per cent of all arc welding is done in this way.

There is another application for the electric arc, however, which is used to some extent in certain classes of work where the weld must be made overhead or on the side of a piece into which the molten metal cannot be dropped. For this application

an electrode of metal is used, this electrode itself being the filler. As the arc is established the metal electrode slowly melts off, sticking onto the part already heated by the arc.

In order to make this process successful it is necessary for the work to be done very slowly compared with the carbon arc method and it is also possible to maintain the arc but a very short time, for as soon as the arc flows long enough to get a bead of melted metal on the end of the electrode, this is touched to the piece to be welded This work, often called "metal electrode" welding, is especially applicable in the case of overhead boiler work or fire-box work where the defective part cannot be placed so that it can be played on by the electric arc over it. In order to successfully accomplish this work it is necessary first of all to have a very small current flowing and also to have this current at a very low voltage. Voltages below 30 are generally used and current values of from 100 to 200 amperes are required. This metal electrode work is very apt to be unsatisfactory unless very carefully done on account of the fact that the metal welded on must be heated to a welding temperature and the point it touches must also be heated to the same temperature, and since the arc is established for but short periods, the positive electrode often does not come up to a welding temperature before the melted bead on the negative electrode must be applied. However, if the work is skilfully handled, successful welds of this kind can be made which will show a very large percentage of the original strength.

The question is often asked, and is one of the most essential ones, "What is the comparative strength of a piece of welded material when compared with the original material?" We hear so many statements regarding this that we are very apt to be misled. In a general way, the statement is true that the weld is equally as strong as the original piece, providing that the original piece is of the same quality and kind of metal as the filler used. This statement, however, does not fully comprehend the difficulties in the way of getting a weld which is as strong as the original piece. In other words, the strength of a piece of cast steel will vary from about 40,000 to 80,000 lbs. A piece of rolled steel will be very considerably stronger than this. A weld in

any of this work would be equally as strong as the metal which is put into the weld when it is considered that the metal has not been rolled or hammered. In a general way, therefore, I would say that a steel casting can be repaired by the use of the arc welder and a weld made the strength of which will exceed 60,000 lbs., which is as strong as the average steel casting. This is to say, the strength of the weld is practically constant when properly made and is approximately 60,000 lbs. per sq. in. Whether it is stronger or weaker than the original piece depends on the strength of the original piece, and in a general way it can be said that the weld is for all practical purposes as strong as the original piece.

This same question comes up in the matter of cast iron, and as a general thing a very good quality of cast iron is used for repairing a gray iron casting. This as a general thing is the best part of the casting and the strength, both tensile and shearing, will be very considerably greater than the original casting. However, it will not exceed the strength of the same metal when merely filled into a mold and whether it is as strong or stronger than the original piece which is welded depends on what the character of the original piece is.

The application of the arc welder is widely varied in the usual foundries and repair shops. There is not a casting which cannot be successfully repaired by the arc. There is not a car or broken locomotive part which cannot be successfully welded by the arc, and all alloys of steel can also be successfully welded. The economies which may be accomplished in this line are so great in number that it is impossible to touch on more than a few of them, but I will take up a few applications.

Steel Castings.

The application in the steel foundries was the first place in which the electric arc was used commercially. Its application here is in patching defective pieces, sand holes and the cutting off of risers and heads. This application is the most popular one which is now being made and its economies are far-reaching. In one case to the writer's knowledge there was a saving made by our welder in a steel foundry which averaged nearly $200 a day

for a period of seven months; that is, taking the castings which were saved by the welder at their selling price compared with the price of scrap for the same castings, plus operating charges.

Broken Machinery.

By this application, the repairing of worn shafts, broken shafts and broken machine castings are repaired for a very small percentage of the cost of new machines. The wearing of a shaft from natural causes or the scoring of the same shaft by a hot bearing is often the cause of great expense in replacement, as is the breaking of machine castings from accident or otherwise. All of these can be successfully repaired with but very little time and cost for the repairs, while the replacing of the entire machine which is otherwise often necessary by the breaking of some part, would be very expensive both in money and in time of shutdown.

Cutting of Steel.

In the cutting of steel, the electric arc has another application. This is used to a great extent in the cutting of risers in steel foundries mentioned above, also in the cutting of sheet, boiler plate, etc. This work can be done very cheaply and very efficiently when compared with punch press, cold saw or any other method of cutting.

The question is often asked, "Can a welded casting be machined as readily as any other part of the casting when electrically welded?" The answer to this is self-evident in case of steel, since a mild steel casting will not harden with quick cooling. In the case of cast iron, however, if the casting is not quickly cooled or if any effort is made to cool it slowly, there is no chance of any difficulty on account of hardness of the weld. I have in my possession a piece of metal ½ in. square and about 1½ in. long made up of steel, copper and cast iron. These were welded into each other by the use of the arc welder. All three of the metals are soft and can be easily worked with the usual machine tools and for all practical purposes are as perfect as if they had been cast and then annealed. This, perhaps, will sound peculiar in the case of gray iron, since a gray iron casting if quickly cooled is very apt to be so hard that it cannot be machined; however,

the iron which is generally used for welding in gray iron is rather high in silicon and is of such a character that when it is not actually quenched by the application of water or cold draught, will make a weld which can be as readily machined as the rest of the casting.

This brings up another point which is very interesting in regard to electric arc welding; that is, that if a high carbon steel is used as a filler, the carbon in it is very largely burned out by the arc itself before the weld is completed, so that the steel in the weld will actually be of very low carbon content. The fillers which are actually used, therefore, in the case of all steel casting work is a soft machinery steel or better a Norway iron, since the carbon content will be practically the same no matter what the original carbon content of the filler may have been. In the case of gray iron a very high silicon iron is used. This also is burned down to a considerable extent, but when the weld is completed there are still all the characteristics of gray iron in the filler.

Operation.

In the case of arc welding, the question is often asked, "Since the efficiency of a weld is so dependent upon the skill of the operator, is it not a difficult thing to get an operator who can make satisfactory welds?" The answer to this is that while it is absolutely important that the welding be done skilfully, yet it is not a difficult thing to get a man who, if he will give his attention to it, can get a weld which is as perfect as the most skilful operator. The whole thing to be remembered, as has been mentioned above, is the fact that the filler and the piece to be welded must be at a welding temperature at the time the filler is applied. If this is done it is absolutely impossible to get anything else but a satisfactory weld. Any man who has good common sense and will apply himself to it, can do most welding successfully within a week's time from the time he starts to work at it, and there are any number of welders who can do the usual work which is required of them within a much shorter time.

Putting the whole process in a few words, I should say: To make a satisfactory arc weld, keep the piece to be welded and the filler at a welding temperature when they come together. If this is done a perfect weld will result. Allowance must be made

for expansion and contraction under heat, but the whole gist of the problem is covered by the above statement. Fluxes, special electrodes, etc., are merely the stage business of the would-be mysterious performer who wants to show his great skill at any cost and takes the most mysterious way possible to do it. Remember that the arc welder is merely a device for heating metal to a welding temperature and that this is its only function. The efficiency of the weld depends on the way the work is done, not the machine.

THE FOUNDRY AND THE PIG IRON MARKET.

By A. I. Findley, New York City.

Foundrymen have been raising the question, as various changes in the blast furnace industry have been reported from time to time, how these are likely to affect the supply and the price of foundry iron. The absorption by steel companies of three merchant furnaces in the Central West—one near Pittsburgh and the others in the Youngstown district—and the expected acquisition of another Mahoning Valley furnace by a steel company, prompted one of these inquiries. It came from a Pittsburgh foundryman who has been for two terms president of the American Foundrymen's Association. He had noticed similar absorptions in Eastern Pennsylvania, one steel company taking over two furnaces which had long produced foundry as well as basic iron, while a second steel company acquired three furnaces in the Lehigh Valley which had for many years marketed a considerable part of their output among Eastern Pennsylvania and New England foundries. Another loss from the merchant furnace ranks, in comparatively recent time, came through the purchase of a Shenango Valley merchant furnace by an ingot mold manufacturer operating in the same city.

The questions foundrymen were interested in having answered were whether these disappearances from the merchant furnace list are signs of a movement which is likely to go farther and what the ultimate effect would be on the market for foundry pig iron. In the same connection other changes in the manufacturing and marketing of foundry pig iron in recent years are attracting attention, suggesting that all developments bearing on the supply of the foundryman's chief raw material might well be considered at the same time. Naturally the year 1907 is one from which reckonings are taken in any inquiry into recent economic changes, and our discussion will have to do, therefore, with the course of the foundry pig iron industry in the past five years, and the indications it gives as to the future.

It is not strange that foundrymen in districts immediately tributary to the Mahoning and Shenango Valleys should be interested in the merchant furnaceman's status. For 15 years it has been precarious. With regularity in that period the passing of the merchant furnaces as a factor in the iron trade of the valleys has been predicted. In years more recent the steel companies have built more and more blast furnaces, and as their buying of pig iron in the market has come at rarer intervals it has been made plain that the merchant furnace producing steel-making iron would find its field of operations constantly narrowing. But no harm could come to the foundryman in all this. Its tendency would be to increase the competition in foundry pig iron, except as new open-hearth steel plants of smaller size were raised up to take the steel-making iron no longer wanted by the large companies.

If we answer our foundryman's question in the light of new blast furnace construction in the past five years, we shall find that any absorptions of merchant furnaces have been far overbalanced by the building of furnaces to make pig iron for the market. Beginning with 1907, the record of additions to merchant furnace capacity, with the estimated yearly output, is as follows:

In 1907, Toledo No. 2, Josephine No. 1, Federal No. 1, Mayville B and Perry, 545,000 gross tons a year.

In 1908, Vanderbilt No. 2, Wickwire X (70 per cent merchant), Miami, Jisco and Ironton, 355,000 tons a year.

In 1909, Federal No. 2, and Cleveland No. 2, 255,000 tons a year.

In 1910, River No. 1, Wickwire Y, and Zug Island No. 2, 350,000 tons a year.

In 1911, River No. 2 and Josephine No. 2 completed, but not blown in until 1912, 250,000 tons a year.

In 1912, two Iroquois and two Rogers-Brown (Buffalo), 510,000 tons a year.

Here is a total of 2,265,000 tons of foundry pig iron capacity added since January 1, 1907, in a period marked, between the panic of October, 1907, and the early summer of 1912, by a demand for foundry products materially less than the average for the three years preceding the panic. Not all of this more than two million tons capacity will necessarily be burdened for foundry iron all the time. Some of it will run on basic iron at times, but it is all

owned by companies engaged in the foundry iron trade and therefore represents potential, and very largely actual, foundry iron production.

It is of interest to note in what districts this expansion in capacity has been most marked. Nearly 75 per cent of it, or 1,665,000 tons a year, is located in Lake cities—South Chicago, Detroit, Toledo, Cleveland, Erie, Buffalo—where Lake ores are unloaded directly into furnace yards and hence where cost of manufacture is low. A further significant fact is that the builders of all of this 75 per cent of the foundry iron capacity added in the past five and a half years have their own ore supply, either by direct ownership or through connected ore interests, and some of them have coke connections. These furnaces, therefore, will be making iron under conditions which would close down many other stacks, as some of them demonstrated in the trying years last past. In fact, if the prices at which some of them sold in the closing months of 1911 are a criterion, there is no probable degree of distress in the foundry trade to which they will not be able to accommodate themselves.

That there has been no such expansion in the foundry capacity of the country in the past five years, as would call for all the product of these nineteen new furnaces, scarcely need be said. It is almost equally obvious that some of these furnaces will market their iron at times by displacing the product of furnaces having higher costs. Something of the course of the foundry industry in the past ten years may be gathered from the statistics of production of foundry iron (including ferro-silicon) and malleable Bessemer which are as follows, as given in the reports of the American Iron and Steel Association.

PRODUCTION OF FOUNDRY AND MALLEABLE BESSEMER PIG IRON, GROSS TONS.

1902	4,162,734	1907	6,071,499
1903	4,882,804	1908	4,052,579
1904	4,090,758	1909	5,980,463
1905	5,393,274	1910	6,103,570
1906	5,472,712	1911	5,081,473

There were imports of a few hundred thousand tons in 1902 and 1903, and another import movement amounting altogether

to about 500,000 tons in 1906 and 1907. But there was also some accumulation at home in 1907 and a more marked home accumulation in 1910. It is probable therefore, that the home consumption of foundry and malleable grades (Bessemer, basic and low phosphorus irons melted by steel foundries are not included above) was under 6,000,000 tons in 1907, one of the two high years in the table, and considerably under that figure in 1910. Last year, in spite of the known reduction of foundry pig iron stocks, the consumption was probably not much above the average for the three lean years preceding, which was so conspicuously reduced by the low rate of 1908. Conditions were thus ripe for the forward movement of which there are so many proofs just now.

The competitive situation in foundry iron in Northern markets has long been thought of as turning on the supply of Southern pig iron. Southern foundry iron has been looked upon as a necessity in certain percentages and for certain uses. More than that, the possibility that on the score of cheapness it would at times displace Northern irons in certain districts has been held up as a check on prices, not only of Northern foundry irons, but of the Lake ores entering into them. The course of the market in the past five or six years has some suggestion on these points. But first it will be of interest to note the contribution of Alabama and Tennessee to the production of foundry iron shown in the table above. For the same ten years the figures are as follows, no account being taken of basic or forge irons:

Production of Foundry Iron—Gross Tons.

	Alabama.	Tennessee.	Total.
1902	1,044,874	328,975	1,373,849
1903	1,194,556	350,966	1,545,522
1904	1,085,935	253,185	1,321,120
1905	1,094,149	311,880	1,406,029
1906	1,117,262	376,722	1,493,984
1907	1,113,340	337,737	1,451,077
1908	884,920	255,945	1,140,865
1909	1,280,798	291,162	1,571,960
1910	1,200,346	308,749	1,509,095
1911	1,240,808	275,091	1,515,899

While Alabama and Tennessee produced 29.5 per cent of the total in the first five years of the ten, they produced but 26

per cent in the second half of the period. It is significant that in the list of twenty-one new furnaces given above, the South contributed only one, and that of 75,000 tons yearly capacity, or 3⅓ per cent of the total. At the same time the South is using more of its foundry iron in its own foundries. Capacity for machinery castings probably has not increased measurably in the South since the panic, but a large radiator plant has been built that will draw most of its iron from the South; a similar plant in Alabama is about to be built and a large Southern soil pipe foundry has been completed. Cast iron pipe works are the main consumers. Some Alabama furnaces are now disposing of about one-third of their foundry iron product south of the Ohio River. It is true that Tennessee furnaces have few closely contributory consumers; but the important fact is that Southern foundry iron is a diminishing factor in the mixtures of Northern foundries.

It has become increasingly evident that price is the determining factor in the marketing of Southern iron. A high phosphorus content has brought a considerably higher price at times for Southern iron from a Northern stove plate or light gray iron foundry. But Northern furnaces have also been meeting the demand for phosphorus. A marked development in the practice of some of those in the Lake cities is the use of higher phosphorus ores, bringing the phosphorus in the pig up to 0.60 to 1.00 per cent and in the case of one iron up to 1.50 per cent. Lake Superior ores answering this purpose are not plentiful, but development in the Crystal Falls district of Michigan is adding to the supply, and in one case a high phosphorus ore from Southern Ohio has been drawn upon by a Lake front furnace.

It is good testimony to the better methods of mixing and melting foundrymen are mastering that they are now able to use to a greater extent than ever the iron that can be delivered the cheapest. In the period of unprofitable prices through which furnacemen have been passing the low quotations in such competitive markets as Chicago and the furnace centers on Lake Erie have alternated between Southern and Northern irons. In Chicago some years ago Northern iron usually brought from 25 to 50 cents a ton higher than Southern. In the recent depression the conditions have been reversed and Northern iron in the Chicago market has undersold that from the South, a condition that still exists.

Much as has been said about the practice of larger foundries of buying their pig iron on analysis, the extent to which classification by numbers has been discarded is probably not appreciated. When the foundryman buys by number he gives the seller a considerable leeway on silicon—50 points usually and if this is stretched out to 75 the average buyer would be none the wiser. With close regulation of his mixture by analysis, the foundryman is now drawing in the lines on silicon and specifying a desired analysis, so that in some cases sales turn on the matter of 0.25 per cent silicon. The recent increase in the use of silicon as the basis of purchases indicates that the time is not far away when pig iron numbers will be eliminated from transactions and the price determined by a specified content of silicon, with other elements exerting an influence on price where an unusual and special content of these is stipulated.

The whole foundry iron situation has been so dominated in the past three years by depressing influences, that one must not generalize too far concerning changes in foundry practice that have had their influence in that period. Aided by the extreme cheapness of basic pig iron, some of the steel foundries have made very low prices, to the displacement at times of forgings and malleable castings and perhaps gray iron castings; but time will be required to show whether the inroad is permanent. Malleable foundries, at the same time, have cheapened their mixture, due to the same cheapness of basic iron, buying off-basic, an iron in which the silicon was higher than steel works would accept. This competition from basic furnaces has affected the price of malleable Bessemer, which has at intervals been below its normal parity with No. 2 foundry iron.

Some very good work has been done in the direction of giving charcoal iron a larger place in car wheel and special mixtures. There have been some results, and the demand upon the railroads for freight car wheels that will better stand the heavy service of recent years is helping the movement. But price is so controlling an influence in railroad buying that the low level of coke pig iron has held down the charcoal product, and much is yet to be done to secure recognition for it on the score of quality. In chilled work and for castings requiring a special selection of raw material, charcoal iron is making headway and the outlook has been suffi-

ciently promising to encourage some addition to the capacity of Michigan charcoal furnaces in the past three years. Lately Mayari pig iron, which owes its properties to a small content of nickel and chromium, has been offered as a component of chilled roll mixtures and for castings requiring special strength.

Throughout the late depression foundry wages have been maintained. There has thus been thrown upon the management the necessity of getting greater efficiency from labor and of introducing every possible economy in mixing and melting, as well as in the mechanical operations of the shops. It was the original intention to include in this paper some data indicating how the shrinkage in market prices for castings in this trying period compared with the decline in prices of pig iron and scrap. A number of representative jobbing foundries were addressed, and while some responded with definite data, there were numerous cases in which the costs of light and heavy work were not so separated as to permit of proper comparisons, due to the varying percentages of these classes of castings from month to month. Possibly this disclosure will supply a text to the advocates of more exact knowledge of foundry costs. So far as the figures furnished permit of deductions, they indicate that foundry pig iron prices in 1911 showed a falling off from the level of 1907 quite equal to and in some cases greater than the shrinkage in prices of castings. The foundryman, with proper attention to his cupola, and with the development of economies in molding machine operation to which hard times furnish the spur, has apparently not fared as badly on the whole as the blast furnaceman.

What has been written above as to the steady increase in foundry iron capacity in Central Western districts in the past five years is not intended to bear on the immediately future course of the market for foundry iron. In that problem a number of factors are involved which cannot be gone into here. But enough has been said to indicate that foundrymen have no reason for anxiety over anything that has happened thus far in the way of absorption of merchant blast furnaces. What has been pointed out as to the lessening of the supply of Southern iron for sale in the North is of interest to Northern foundrymen regularly depending on such iron for a part of their mixture. But the factor of first importance in the whole question of foundry iron supply

and demand is the prodigious addition made in and since 1907 to the foundry iron capacity of the country. Of chief significance in that connection is the fact that in the Lake cities, from Buffalo on the east to South Chicago on the west, such additions have brought the foundry capacity of these cities up to 3,000,000 tons a year. In other words, this cordon of twenty-seven furnaces between the foot of Lake Michigan and the foot of Lake Erie now represents a capacity equal to half the consumption of foundry iron in the United States in the high record year. The question of supply, and generally speaking at a moderate level of prices, is therefore one about which foundrymen need have no early concern.

THE PREMIUM SYSTEM AS APPLIED TO THE FINISHING DEPARTMENT OF A STEEL FOUNDRY.

By G. A. W. Gregg, South Milwaukee, Wis.

The steel foundry referred to in the following is connected with a manufacturing establishment which builds steam and electric shovels—several types of large dredges, pile-drivers, dragline excavators and other heavy machinery. The castings made vary from a few pounds to ten and eleven tons each. Only a little over one-third of the work is standard, and even the so-called standard work is subject to frequent change in the course of improvement in design. In other words, the work is practically job-work.

Premium system of payment was introduced for the molding several years previous to the proposal to use it in the cleaning room. Molding rates are set on individual jobs after time study—the rate being obtained by adding 60 per cent to the proper time to do the job—the bonus to the molder being one-half the time saved. This gives a man doing the work in the proper time an increase in pay of 30 per cent. The proper time is considered to be the time in which the average good man, working under average good conditions, can do the job, no account being taken of unfortunate circumstances, such as breaking a core, a delay for the crane, etc.

The labor employed in the foundry cleaning room is nearly all foreign born, composed of Polish, Greek, Hungarian, Slavish and Armenian laborers, about one in twenty of whom speaks English, and grave doubt was entertained as to the possibility of making this class of labor comprehend the idea of a premium rate. If this fear had been well founded no results could have been accomplished because the object of setting rates is to increase production and this object is defeated unless the men strive to earn premium. Also any premium paid to a man who is not striving to earn it is a gift pure and simple. Experience quickly

proved that these men could grasp the idea of increased pay for increased output, and that they were more than anxious to earn the extra money.

Undoubtedly the fact that the molding was rated made it far easier to secure the co-operation of the men when rates were set in the cleaning room, for it was generally known among the chippers that the molders earned good wages through the premium system.

The method of premium payment as finally adopted for the cleaning of castings will be first described, followed by an explanation of the steps by which it was developed.

The work is divided into five natural classes—sand-blasting, saw-work, sledge and cold-cut work, grinding and air-hammer work.

The basis selected for setting rates was weight, and curves have been developed expressing the rate plotted against the weight of the casting for the air-hammer, grinding and sledge work. The rate is the proper time to do the job plus 100 per cent, the bonus to the man being one-quarter of the time saved; thus permitting a man who does the work in the proper time to earn an increase of 25 per cent in wages. The selection of 25 per cent, which has proved to be ample, was caused by a desire to play safe, for the nature of the work makes it very difficult to determine the proper time. The method of rating sand-blasting and sawing will be mentioned later, for they are handled in a different manner from the other three.

A time-keeper records the work for each man precisely as if the rates were set to pattern mark,—keeping a record of the time in which each job is done. The time card has a space for the weight of the casting after its pattern mark, and this is filled in by the time checker, who then gets the rate from the proper curve and marks it on the card.

The time put in by each man each day is subtracted from the sum of the time limits for the work completed on that day, and one-quarter of the difference is awarded to the man as a bonus.

The premium system of payment has added two men to the clerical force as indicated above: namely, a time-keeper and a time checker. If the rates were set to pattern mark a third man would be necessary to make time studies and set rates—the selection of weight as the basis and the use of curves obviates the necessity of a rate setter.

The points of interest are the quarter system of premium payment and the method by which the curves were developed.

The first experiments in setting rates on cleaning room work were made on the air-hammer work. The time to clean a rather standard casting was carefully studied by the foreman, with two of the best and most intelligent workmen doing the work. After deciding on the proper time, 50 per cent was added, and this rate work was given to the men with a careful explanation that half of the time saved would be awarded as a bonus. The output of these two men increased in such a gratifying manner that a dozen or more additional rates were set. After the first pay day all the men began to ask for premium work. The curious discovery was made that it was not necessary to tell the men what rate had been set on a job. They were satisfied to know that a rate had been set, and to urge a man to his best efforts it was only necessary for the foreman to pull out his watch—point to a job and utter the magic word "premium." The men from the start seemed to assume that the rates set would be fair and that hard work would be rewarded by increased pay.

The result of setting rates was so uniformly encouraging that more and more were set. For the first four months the foreman set all the rates and he and his assistant kept time on the work. By the end of this time, 75 per cent of the work going through was kept constantly rated and it was found necessary to employ a time-keeper. Also the task of setting so many rates was taking such a large share of the foreman's time that it was necessary to devise some wholesale method of rating or secure a man to set rates.

The happy idea of putting the rating on a weight basis was suggested. During the first four months upward of 2000 rates had been set, and the first step was to go over these rates to see if there was any definite relation between weight and rate. To do this the output per rate hour was calculated for each of the rates which had been set by time study.

The rates plotted against the weight of castings gave a surprisingly smooth curve. Naturally, the output per hour in pounds increases very rapidly as the weight of the casting increases.

The curves were checked against the old time-cards for several weeks back and it was found that the premium earned by

the gang as a whole averaged about the same with rates set from the curves as under the individual rates.

However, it was also found that the earnings of some men ran much higher and others much lower than under the old rates and that this variation did not altogether represent a variation in the ability of the men.

The curves it seemed would give the total premium earnings for the gang correctly, but the distribution to the individual laborer was not altogether equitable.

Several methods were considered to overcome this difficulty, but the one finally adopted was the quarter system. Previous to this time the curves had been based (as the individual rates were) on an addition of 50 per cent to the proper time and one-half of the time saved as a bonus.

With the quarter system as before stated, 100 per cent is added to the proper time and one-quarter of the time saved is paid as a bonus.

An example will probably be the easier way in which to show that the quarter system will tend to neutralize the effect of a man getting a lot of jobs which require either more or less than the average amount of work. Suppose the proper time to clean the average casting from a certain pattern is ten hours. The following table shows the percentage of premium earned under both systems under three different conditions: First, work done in proper time; second, done in much less than the proper time; third, done in more than the proper time.

	Proper time.	Premium rate.	Bonus earned if job is done in proper time.	Bonus earned if job is done in 4 hours. Much less than proper time.	Bonus earned if job is done in 12 hours. Longer than proper time.
One half System........	10	15	2½ hrs or 25%	5½ hrs or 137½%	1½ hrs or 12½%
One-quarter System.....	10	20	2½ hrs or 25%	4 hrs or 100 %	2 hrs or 16⅔%

Under the quarter system it is evident that a fortunate run of work will not so materially increase a man's earnings—nor will an exceptionally unfortunate run of work so materially decrease them.

To illustrate the same thing in a different manner, the curves in Fig. 1 have been drawn which show the variation in wages under piece work, one-half premium system and one-quarter premium system resulting from doing a job in different lengths

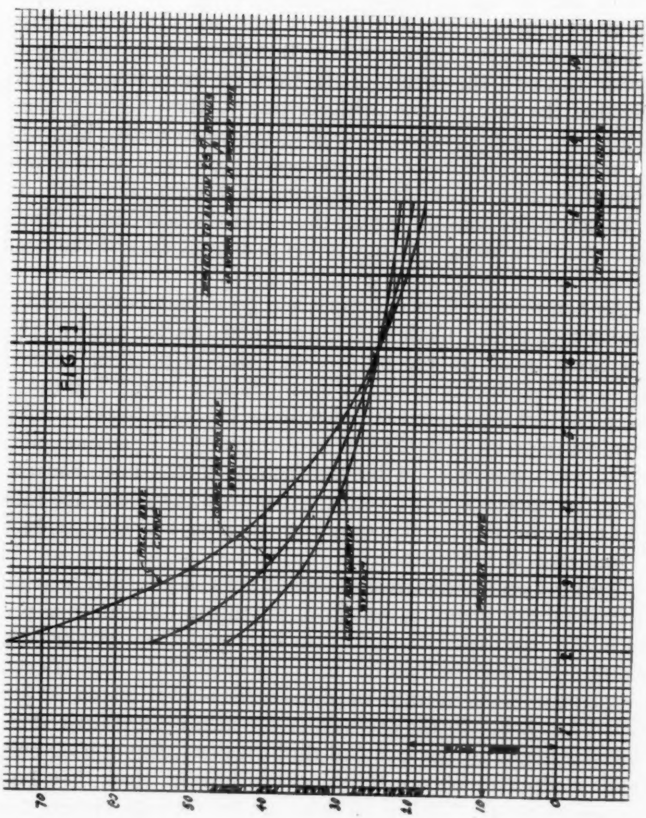


FIG. 1.

of time. The same conditions are used in each of the three cases —namely a base rate of 20 cents and a bonus of 25 per cent if the work is done in the proper time. Where the proper time to do a given job can be determined with great accuracy, piece work or the one-half premium system will give the best results, because the reward for increased output and the penalty for decreased output are both greater. But where, as in the case of cleaning castings, the nature of the work makes it impossible to determine the proper time with certainty, the quarter system will give the most satisfactory results because fortunate jobs will not increase the bonus earned so rapidly, and neither will unfortunate ones cut off entirely the chance to earn premium. It will be noted also that the curves show that the disciplinary effect of the quarter system very nearly approximates that of the one-half system.

Air-hammer work, sledge work and grinding are all rated by the above described method of curves and quarter system, the rates being based on the output per hour in pounds. Sand-blasting and saw-work are rated in a different way. The sand-blast work had been rated at a definite price in cents per ton for several years previous to the rating of chipping and grinding, and as this was considered to be satisfactory it was not changed. Rating the saw-work was a comparatively easy problem, the rate being based on the lineal inches cut per hour and the one-half premium system being used.

Reduced cost and increased output are the principal benefits obtained by the premium system of payment. The output per man in the case under discussion has increased about 60 per cent since the men have had an incentive to exert their best efforts. The increase in the average wage has amounted to about 20 per cent. The change in the attitude of the men toward their work is well illustrated by the fact that they are now using at their own request sledges which are three pounds heavier than they had been using before. When working under the old system the foreman was very often compelled to discharge men for grinding sledges on an emery wheel to make them lighter. Such a change of attitude, of course, makes the work of supervision a far less exacting task, and the increased earnings have resulted in a better contented and more efficient lot of workmen.

FURTHER NOTES ON THE USE OF TITANIUM IN MALLEABLE CASTINGS.

By C. H. Gale, Pittsburgh, Pa.

In following up the experiments made with ferro-titanium in malleable castings as given in a paper on this subject presented at the Pittsburgh Convention of 1911, an alloy of different composition was used, being as follows:

Iron	70.18
Titanium	20.66
Aluminum	7.46
Carbon	.84
Silicon	.83

The tests were all made from the open-hearth furnace and the usual daily product.

Table 1.

Mark.	Tensile strength, lbs. per sq. in.	Per cent elongation, in 6 in.	Remarks.
0	47,650	5.7	No Titanium alloy added.
	49,500	6.2	
	49,730	6.2	
1	45,800	4.1	0.25% Titanium alloy added
	45,290	6.2	to 5 ton ladle, or 0.05 Ti.
	47,910	6.2	and 0.02 Al. added.
2	55,328	5.2	No Titanium alloy added.
	56,587	6.7	
	49,679	6.7	
3	43,380	4.1	0.25% Ti. alloy added to
	49,030	5.2	hand ladles, or 0.05 Ti.
	48,510	6.2	and 0.02 Al.
4	47,920	6.2	0.30% Ti. alloy added to
	48,210	5.2	hand ladles, or 0.06 Ti.
	48,110	6.2	and 0.02 Al.
5	44,644	5.7	0.35% Ti. alloy added to
	45,980	6.2	hand ladles, or 0.07 Ti.
	45,670	5.2	and 0.03 Al.

Nos. 0 and 1 were cast from one heat of fifteen tons, and the other numbers from another heat of the same size.

As the above results indicate that the metal was better in its original state, the fact that possibly the aluminum content of the alloy may have militated against its strength was taken into consideration, and another series of tests with less alloy instituted.

It may be stated here that recent investigations have shown very plainly that when deoxidation is effected by such metals as aluminum, a film of aluminum oxide of infinitesimal thickness may remain between the individual crystals of metal, and hence while these have been freed from oxidation, they are not in as close a state of adhesion as they should be. Only standing for some time under full heat will allow the metal to free itself from this condition, the aluminum oxide rising to the top and passing into the slag. Hence better results can be obtained by the addition of the alloy to the bath or large receiving ladle than when added to the small pouring ladle.

The further tests with smaller amounts of the alloy give the following results:

TABLE 2.

Mark.	Ultimate strength. lbs. per sq. in.	Per cent elongation in 6 in.	Remarks.
0	49,560	5.7	No Ti. alloy added.
	50,240	4.6	
	51,940	5.2	
1	48,860	5.2	0.15% Titanium alloy added,
	49,420	5.2	or 0.03 Ti. and 0.01 Al.
	49,970	5.7	
3	52,490	5.7	No Ti. alloy added.
	49,850	5.2	
	50,870	5.4	
2	53,170	5.7	0.20% Ti. alloy added. Or
	55,230	6.7	0.04 Ti. and 0.015 Al.
	55,510	8.8	

Nos. 0 and 1 were from the same heat and Nos. 3 and 2 from another heat. There is a noticeable improvement to be seen in the last instance.

Transverse tests were made for this series of tests, and the results are given herewith:

TABLE 3.

Bars ½ in. x 1 in. Section.

Mark.	Load applied in lbs. Supports 12 in. apart.	Deflection in in.	Remarks.
0	1,270	1.80+	Beyond capacity of machine
	1,300	1.80+	for deflection.
1	1,350	1.80+	
	1,290	1.80+	
	1,310	1.80+	
	1,330	1.80+	
	1,360	1.80+	
3	1,210	1.80+	
	1,250	1.10	Heavy shrinkage.
2	1,380	1.80+	
	1,425	1.80+	
	1,320	1.80+	

These transverse tests would seem to confirm the advantage of the slight titanium addition. Unfortunately for the tests, the metal used was of so good a quality—as shown by the untreated bars—that the intended improvement by the use of titanium cannot be very well judged. Probably where the air furnace is used, where oxidation is more marked, and less attention given to getting out the heats quickly, the results might have been more conspicuous. What the bending strength would have been had the above bars failed under continued deflection cannot be stated, as the machine could not measure it. The results are given more particularly to show that when one has good metal, deoxidizing alloys are not necessary, with the obvious inference that it is better to make a good metal than to correct an inferior product.

OPEN-HEARTH FURNACE DESIGN AND MANIPULATION AS ADOPTED FOR FOUNDRY WORK.

By John H. Ploehn, Davenport, Ia.

While considerable has been published about open-hearth furnaces with respect to general proportion and outline, there can be found very little on the refinements and details that play a very important part in the up-keep, manipulation and life of a basic open-hearth furnace.

Instead of comparisons of different types and kinds of open-hearth furnaces, this paper will be confined to a description and the proportion, areas and various main dimensions of the twenty-five ton basic open-hearth furnaces in operation in the steel foundry of the Bettendorf Axle Company.

The results obtained from these furnaces in time, quality and life have been exceptional. The average time of 2,000 heats in the two furnaces has been 5½ hours on an average per heat of 22½ tons. The record of these furnaces is a 25-ton heat made in 4 hours and 30 minutes, but all conditions were perfect to make this time. The charge was well balanced, the furnace comparatively new, and no trouble experienced with the bottom or slag.

The average analysis of this same number of heats has been: carbon, .205 per cent; silicon, .315 per cent; manganese, .68 per cent; phosphorus, .018 per cent, and sulphur, .024 per cent.

The life, or number of heats made before shutting the furnaces down for repairs, has been as follows:

Initial run of No. 1 furnace, 403 heats; second run of this furnace is now over 609 heats, and it looks as if it is still good for at least forty or fifty more heats. The initial run of No. 2 furnace was 573 heats, and the second run of this same furnace was 401 heats.

These furnaces were designed for using either fuel oil or producer gas, but up to the present time have been operated entirely on fuel oil. The chief feature of the design is the ample

and generous proportions allowed in all portions of the furnace. The bath is both longer and wider, and from such little observation as the writer has been able to make, it is greater in these dimensions than is ordinarily found in this size furnace. When burning fuel oil a furnace should be much longer than when burning either natural or producer gas; how much is the question. In this case the furnaces are 10 ft. longer than the average gas-burning furnace of the same capacity. On account of this extra length it is possible to obtain complete combustion before the center of furnace is reached, and thence on toward the other port the flame, having lost its cutting action and sharpness, very closely resembles a gas flame in appearance and action. For a 25-ton heat, the bath is neither shallow nor deep, but what could be called a medium depth, which seems to give better, quicker and more uniform quality of metal than either a shallow or a deep bath. The depth of bath for a 25-ton heat is approximately 16 to 17 in. The area of the hearth is 260 sq. ft., which allows a trifle more than 10 sq. ft. per ton.

The general outline and dimensions of the hearth are shown by Fig. 1. At the port ends, it will be noticed that there is no "dog-house or monkey," these being omitted by using water-cooled oil burners. The area of the flues or up-takes leading to the slag pockets is 28 sq. ft. for each end of the furnace. The distance from the hearth-bridge to the under-side of the roof is greater than the width of the ports, and the area at this point is 40 sq. ft. at each end of the furnace.

Particularly when using oil, the construction of the ends of the furnace requires especial care, as the flame is inclined to be extremely sharp and will cut out the ends of a furnace in a short time. This is practically entirely prevented by the extra length before mentioned and the large areas at the points mentioned above.

These furnaces were first designed with a hip roof and with the side walls contracted 12 in. at the port ends. After the initial run of each furnace, both the side walls and roof were made straight.

With the hip roof and contracted sides, both the roof at the hip, and particularly the side walls at the point of contraction, were cut away on the inside long before the adjoining parts of the roof and walls were badly damaged.

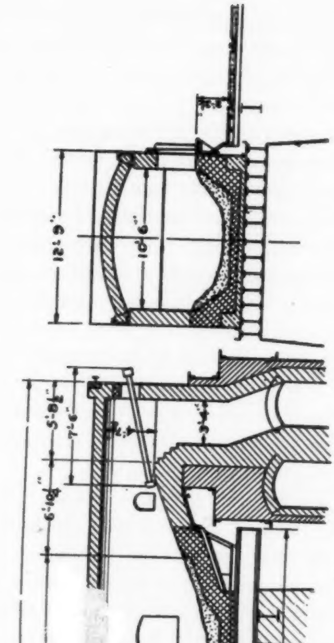


FIG. 1.

The expansion and contraction lengthwise is also better taken care of with straight walls and roof than with the hip roof and contracted ends.

A small door is provided in each end of the furnace near the burner, approximately half-way between the top of the hearth-bridge wall and the end of the hearth, and it has been found to be very useful for inspecting the end of the furnace, and also for watching the action of the burners and the flame at this point.

The water-cooled burners, while requiring water for their operation, which in some localities would be quite an item of expense, have a great many advantages which more than offset the cost of the water required for their operation. The most important advantage is the fact that the flame can be correctly located and positively kept in that location, because the burners are left in the furnace at all times. The burner tip, being water cooled, is not liable to give trouble with the oil coking, which is the case with the plain burner.

The general outline of the way these burners have been installed on these furnaces is shown by Fig. 2. The burners can be moved horizontally or vertically, and the tip of the burner can be elevated or depressed as may be required. The oil and air connections, being stationary, cause less trouble than on burners where the same are pulled in and out at every reversal of the furnace.

Fig. 2 also shows a further use of the water after leaving the burner. The water from the main is first led into the burner, and from the burner into a bulkhead through which the burner passes. From the bulkhead the water is led to a sewer. The use of this bulkhead is to support the burner, and also makes possible a smaller opening for the burner than through an arch brick opening, and being a cooler wall, lasts much longer and makes it possible and more comfortable for the melter to look into the end of the furnace for inspection of the roof and the flame. With water-cooled burners the furnace is reversed more uniformly and regularly, as it does not require the melter to climb over charging cars, etc., to pull out and shove in the burners, saving a walk of about one hundred feet every twenty minutes, conserving this time and strength for better purposes.

These furnaces have always been lighted at the slag pockets,

which heats the checker brick quicker and is much easier on the new brickwork above, and does away with most of the preliminary heating in the hearth, also keeping all ashes and refuse out of the hearth.

The doors and door frames are water cooled, this feature not only protecting the door jambs, but a feature appreciated by the melters, especially in the summer. The door frames run from 400 to 600 heats, the center frame usually failing first. When the water jackets on the doors are burned out, they are re-lined solid with fire-brick and used during the winter months.

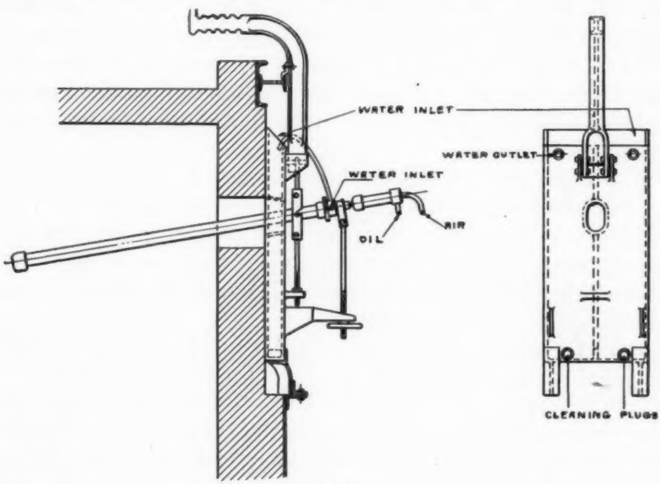


FIG. 2.

The use of coarsely ground chrome ore has been found very valuable for patching door jambs and front and back walls at the slag line. It sinters easily on vertical surfaces and makes a more permanent and lasting repair than magnesite.

Another advantage in having large areas at the end of the furnace is that the velocity of the outgoing gases is decreased so that the slag is not carried over into the slag pockets in any great masses or in a molten condition. With ample areas, the top of the hearth-bridge wall should also be at least 2 ft. above normal slag line; in this design, this dimension is very nearly 2 ft. 6 in.

A detail that is often overlooked is the intersection of the bridge-hearth and port or flue. This is very often brought up to a square corner, which requires the outgoing gases to continue toward the end walls before going downward. To allow the gases to assume as near as possible their natural flow in turning downward, the intersection of the port and the hearth-bridge should be on an angle of about forty-five degrees.

During the two runs of these two furnaces, the slag in slag pockets has been in a granular or lumpy state, so that it was easily removed with pick and shovel without injury to the slag pocket walls, in two days after the shut-down. A false bottom of old steel plates covered with brick-bats and silica sand is placed 4 in. above the floor of slag pockets, this air space under the entire slag pocket serving to chill the slag and keep the pockets cooler than if same had a solid floor. The area of the slag pockets is 90 sq. feet.

The slope of the checker bridge begins 1 ft. inside of slag pocket, and extends into the checker chambers a distance of 7 ft. This easy slope allows free passage of the gases and prevents the retarding of gases due to too abrupt deflection against port ends or the checker chamber roof. The area of opening above checker bridge wall is 28 sq. ft.

The checkers are directly in the rear of the slag pockets and are of very large proportions, the actual volume being 120 cu. ft. per ton. In addition to this extraordinary volume all the checker brick are of silica, and the results so far obtained prove that it is a good investment, taking into account the additional first cost of silica brick over fire-brick.

After both the initial and second run of each furnace, the only repairs required for these checkers was a thorough cleaning, and from their present condition the checker brick will be good for at least another run of 500 heats, and then only the upper five or six courses will probably be replaced with new brick. The silica brick seem to have a greater capacity for storing, and are quicker to absorb heat than clay brick.

The area underneath the checker brick should be large, so that the incoming and outgoing air and gases can distribute themselves uniformly through the various passages between the checker brick. The area of the flues under the checker brick in the air

chamber is 12 sq. ft., and in the gas chamber is 8 sq. ft. The area of the flue leading from the checker chambers to the valve is 12 sq. ft. and this same area is maintained through the valve and in the flue leading from the valve to the stack.

For convenience in cleaning out the flues leading from the checkers to the valve when the furnace is down for repairs a cast iron rectangular manhole and cover is placed in the roof of the flue directly back of the center of the checker chambers. This manhole saves considerable time when cleaning out these flues under the checker brick, and so far has not become warped or leaky.

As the area of the flue leading to the reversing valve is practically the determining area, a summary is given below of the various areas mentioned above, assuming this area as unity.

Area under checker chambers	1.66
Area over checker bridge wall	2.3
Area in ports from slag pockets to port ends	2.3
Area over hearth-bridge wall	3.3

To prevent water from accummulating in any of the flues or checker chambers, a drain is located in each flue and chamber, which is connected to a sewer discharging into a deep well, from which the water is pumped by an automatic electric sump pump. A horizontal "U" trap is placed below each drain, so that the air or gas cannot short circuit or pass from one chamber or flue to another.

With these furnaces was tried radical brick stacks, lined with fire-brick their entire height. The height of stacks is 125 ft., and the diameter inside at the bottom is 5 ft. 9 in., and at the top, 4 ft. 6 in. These stacks have been in service for three years, and have as yet shown no cracks or weaknesses. The advantages gained are that they do not require painting every year, do not corrode, and are not affected by gases, and being a poorer conductor of heat, will maintain a higher temperature, and subsequently better draft than a steel brick-lined stack of the same height.

While drying out, and after the oil has been started, the roof of a furnace is a peculiar and particularly tricky structure. The life of a roof is practically determined by the treatment it gets and its behavior during the first fifty heats.

To facilitate letting out the roof tie rods, both the nuts and tie rods are locked on the back or tapping side of the furnace, so that all expansion and contraction can be taken up by loosening or tightening the nuts on the front side of the furnace, saving thereby considerable time and allowing the amount of lengthening and shortening to be more accurately measured.

To prevent getting the roof out of shape in its earlier stages, a roof rigging was put on which is simple in its construction and has been found to be very useful and effective in holding the true arch shape of the roof until the roof brick are glazed enough to be practically one continuous mass.

The rigging is shown by Fig. 3, and consists of three rails extending the entire length of the roof. The rails are suspended from cross beams which are supported on the side buck-staves. Between the rail clamps and the cross beams, wedges can be introduced to bring pressure on any particular rail when the weight of the rail alone is not sufficient. If necessary, the weight of the rail may be lifted entirely and be free from the roof if same should be found necessary. The cross beams are not rigidly connected to the side buck-staves, and the expansion and contraction of the roof are taken up by the tie rods.

With this rigging, the bulging of a thin part of the roof can be controlled and in most cases gradually brought back to the original true arch. An inspection of furnace No. 1, which has this rigging on, shows that the roof still has its original true arch shape and that it has burned off uniformly on the inside, to which, of course, proper credit should be given to the melter for careful handling of the furnace.

On these furnaces, the skew-back channels are rigidly connected to the buck-staves so that the roof is entirely free from the side walls. A space is left below the skew-back channels so that the vertical expansion of the side walls can be taken care of. This keeps the roof practically straight in its length, and thereby makes it stronger and of longer life than if the skew-backs rested on the side walls and moved up and down or varied with the same.

Below are given a few refinements and accessories, which, although not necessary, have proved to be a good investment. To some they may seem unnecessary, as an old open-hearth melter remarked: "If you haven't got a good man on the furnace who

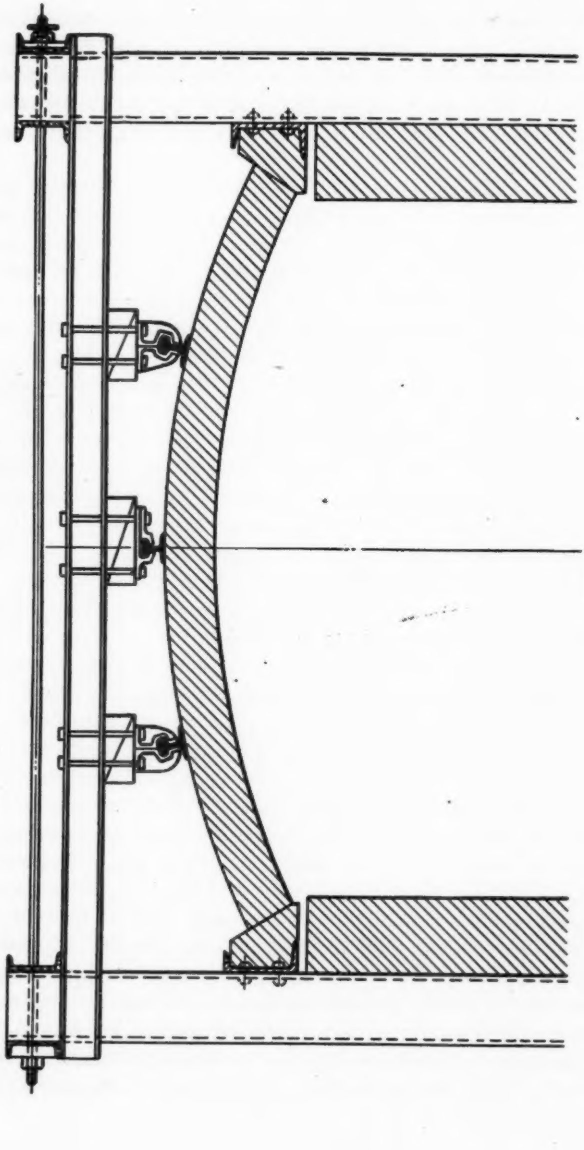


FIG. 3.

you can depend on to reverse her when time, and who don't know when his valves ain't working right, and who can't regulate his damper according to the way the furnace is working, why, fire him and get some one that can do it right." But that is easier said than done—and the next man may be worse than the one before.

A level-headed melter will appreciate and recognize the value of recording gauges and appliances that will show him the actual conditions of the elements that control his product, and they will be an incentive, and on the other hand not be an excuse for not getting good product, even if not able to improve same.

When these furnaces were new, some heats were wild and over-oxidized, and after analyzing all the conditions and charges, the trouble was finally located as being due to excessive draft under certain weather conditions. To regulate this, a recording draft gauge was installed and this has proved to be a very valuable instrument. The damper can be regulated to give the same amount of draft for all conditions of weather and furnace, and the results have been accordingly more uniform.

For this particular design of furnace and stack, the draft that gave the best results was .8 in. of water. Being recording, it gives a history of the day's run and permanent record for future comparison. A sample chart is shown in Fig. 4.

An air-controlled butterfly valve is used on these furnaces, and to give the operator warning that the valve is not entirely closed, a small, inexpensive electrical device was installed. It consists of a contact point at the end of stroke, which, when the valve is closed, closes the circuit and lights a light on the platform. As the valves are usually under the platform and out of sight of the operator, it is hard to detect leaky valves, which, if allowed to continue, in time cause serious delay and trouble.

Another cause for oxidized metal was found to be due to the admission of too much air at the reversing valve. To give the operator the necessary information and to prevent guesswork the screw stand on the platform was calibrated to show exactly the number of inches the doors are open. Since this was done the doors are open only about one-half as much as before.

The practice of using too high air or steam pressures has been found to be injurious to quality. The pressures necessary vary

for different furnaces and conditions. For these furnaces, the air pressure during melting the heat is about sixty pounds, and during the time of working, about forty pounds; the oil pressure being slightly higher, or lower, depending on the kind of burner or atomizer used and the distance necessary to pump same.

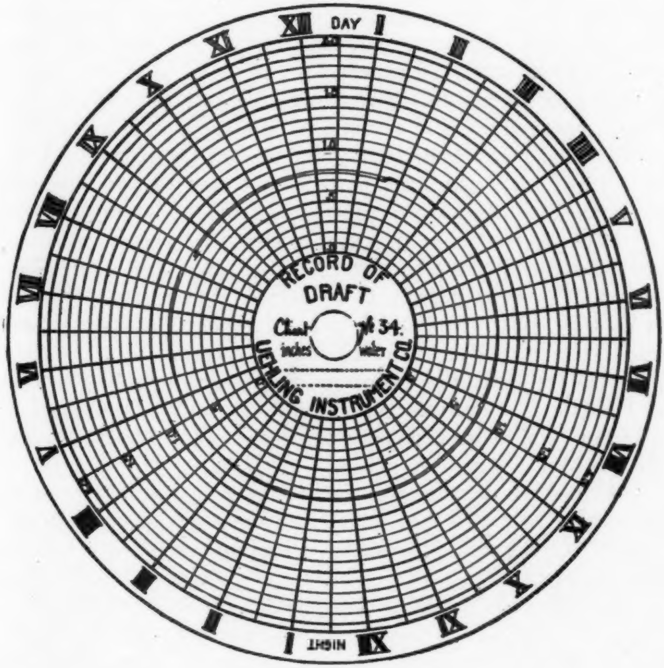


FIG. 4.

Various methods have been used to cover the steel plate of charging platforms, but none seem to give perfect satisfaction or able to stand the heat or hard usage. As an experiment, a cinder concrete floor was laid on the steel plate, and of a thickness so as to be level with the charging machine rails. This is shown in Fig. 5. To prevent corrosion of the steel plate in contact with the cinder concrete, a sheet of heavy tar paper was first laid on

the steel plate. This floor has stood the hard service of three years' operation, and is in splendid condition at the present time.

This flush concrete floor has the advantage of being able to wheel across the tracks the materials used for the furnaces, furnishes the melter and helpers with a better and surer footing for rabbling out a puddle hole or when tapping heats, and is also far cooler than a bare plate floor.

Next to the furnace, removable cast plates in sections of 4 ft. in length are laid even with the rails.

Bins for storing the various materials used on the charging platform not only save a waste, but also make a safer and cleaner working floor. They are easily and cheaply built of a bottom plate with sides, ends and partitions riveted to same, leaving the entire side facing the furnace open for easy access for shoveling. The sides extend to a height to clear the charging machine, and the materials must be kept below that level. It is surprising the amount of materials that can be placed in a small, confined area. The several bins for one furnace are about as long as one-half the length of the furnace, but in them are kept sufficient materials for a week of fluor-spar, magnesite, burned lime, iron ore, dolomite and chrome ore. The bins set on the concrete floor, but are not fastened in any way, so they can be easily moved in case of furnace repairs.

Besides the draft gauge, both recording oil and air pressure gauges are used, and they have been found valuable to tell the melter of any increase in pressure, especially of oil, which often creeps up gradually. A sample air gauge chart is shown in Fig. 6, and oil gauge chart in Fig. 7.

It is true that the basic open-hearth furnace is a scavenger, and will make steel out of any kind of stock, yet to maintain uniform analysis, dead metal and the high temperature necessary for the general steel castings, great care and judgment are necessary in the kind and proportions of the stock charged.

Thin and light scrap, especially when badly rusted, should be avoided, because not only is the percentage of loss higher in the furnace, but the large amount of oxides is hard on the basic lining and very liable to produce an over-oxidized, or "wild" metal.

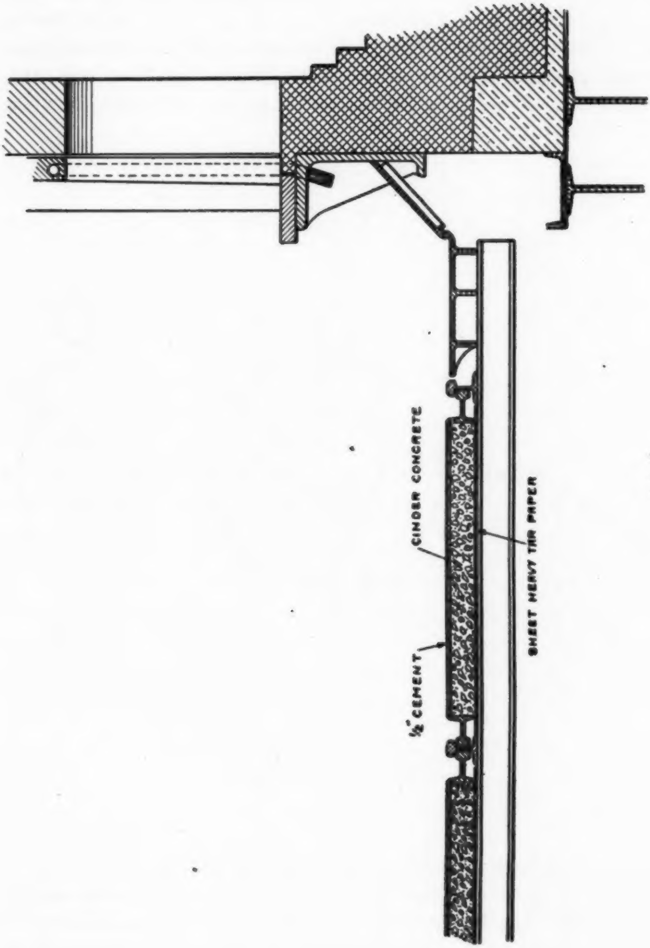


FIG. 5.

To arrive at the proper proportions necessary for different kinds of scrap, a series of test heats was made, in which the percentage of pig iron was varied from 50 per cent to as low as 31 per cent, the various kinds of scrap making up the remainder of the charge. The percentage of different kinds of scrap was varied according to their carbon content. The pig iron was

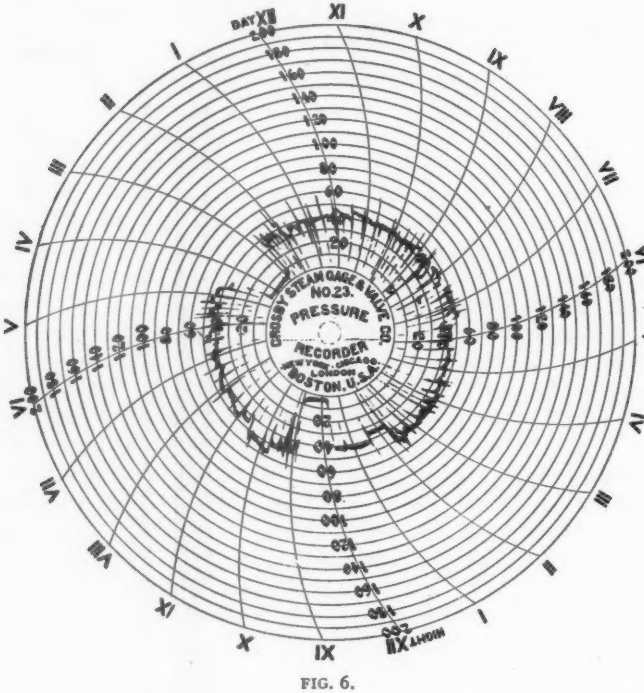


FIG. 6.

assumed at 3.00 per cent carbon, and the carbon content of the scrap had to be sufficient so that the calculated carbon of the charge was not lower than 1.00 per cent, with an average of 1.25 per cent. There was a total of approximately fifty heats in this test, and the time of heat, final analysis and kind of metal of any one of these tests did not vary to any appreciable extent from the grand average of all heats.

This proved conclusively that scrap of different carbon content should be kept in separate piles, and the following classifications resulted.

Scrap of carbon content up to 30 per cent is kept in one pile or bin. In this class are structural shearings and short structural sections, couplers and knuckles, and shop scrap.

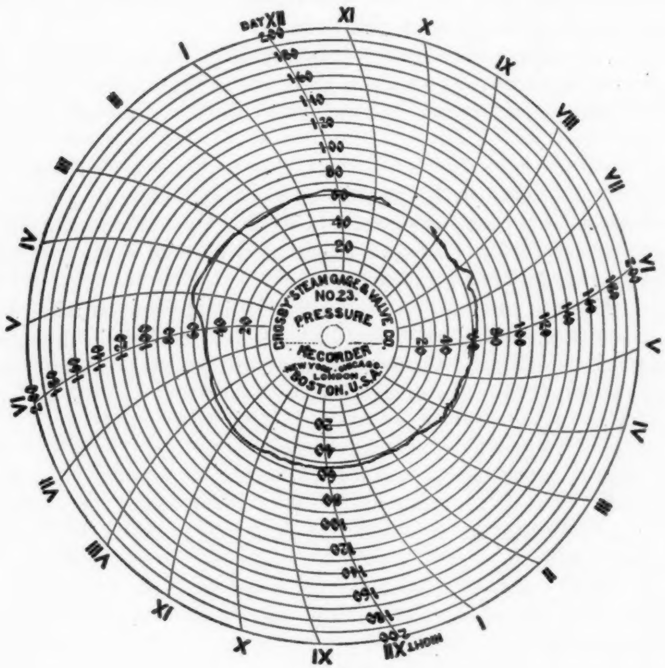


FIG. 7.

Scrap of carbon content from 30 per cent to 60 per cent is the second class. In this class are old rails, etc.

The last class is scrap of carbon content above 60 per cent. In this class are springs, old rolls, etc.

At this plant, to be able to store an ample supply of charging materials under roof, not only for advantage gained in the winter months, but also to be able to separate the various classes of scrap

as mentioned above, huge reinforced concrete bins were built in the furnace bay. The sides and ends of all these bins are 14 ft. above the floor level, the bottom of the bins extending 4 ft. below the floor to bed rock. Half of the bins are for pig iron, the iron from different concerns, or of "off" analysis being kept separate. The unloading of cars and the loading of charging boxes is done entirely by electric magnets, which makes possible the storage of materials in bins 14 ft. high.

To facilitate keeping these various kinds separate, it is necessary, when purchasing scrap, to specify that the various kinds be shipped in separate cars, and this can be done without additional cost.

If it is left to the yard or stock man to make up the charges, usually the scrap that is nearest at hand, or in his way, is sent to the furnaces, the consequence being that some heats melt high and some soft, introducing an unnecessary element of uncertainty in the time and quality of the product.

When it can be depended that the heats can be made in certain time, the cycle of smooth operation is reached, in that the time of charging and the work on the molding and pouring floors can be arranged to better advantage.

CAST IRON AT THE SIXTH CONGRESS OF THE INTERNATIONAL SOCIETY FOR TESTING MATERIALS.

BY THE SECRETARY.

What seemed but a passing remark by one of Germany's famous metallographists, when discussing the failure of metals which had been properly handled and were of good composition, contained, in the estimation of your secretary, the most important point brought out in that great gathering of the world's foremost experts in New York City a few weeks ago. It came about in summing up the questions relating to slag inclusions in steel and cast iron; or, in other words, the presence of foreign particles, in mechanical admixture, in material of otherwise perfect composition and which had received the best known heat treatment adapted to the requirements of the case.

This expert investigator had found that in what seemed unexplainable cases of failure of steel, and other metals and alloys where the material would seem to come apart by one portion sliding over another when subjected to heavy stress, a close microscopical examination indicated the presence of an infinitesimal layer of oxidized material, slag, or other inclusions which could not be worked out under ordinary hammering or rolling. This was particularly noticeable in cast aluminum, and metals liable to oxidation. It was the explanation of many a failure in service, and its solution seemed to lie solely in giving the molten metal time enough while at its maximum temperature in the furnace to free itself from all such extraneous materials which had nothing to do with the chemical composition. He called attention to the fact that if a heat of steel ready for making castings can be kept in the furnace for another twenty minutes before tapping, so that the minute products of oxidation, as well as the oxidized portions of the ferro-alloy additions, slag, and the like, can rise to the top into the slag cover, *that* steel will give superior castings, if the com-

position was right. The electric furnace when applied as a finishing process to a heat of steel did just this thing. It allowed the steel to become extremely hot while remaining perfectly quiet. Time was given the metal to free itself of a maximum of impurities present mechanically, with the result of special excellence in service. It seemed to be the solution of the steel rail problem.

For us foundrymen there can be taken from this some obvious lessons: The steel founder can see the point at once, but the iron founder will need time to gather profit from the suggestion. We now know that we get cleaner iron from metal which has stood for some time in the ladle before pouring, but we do not know that we can cut our sulphur content very materially by allowing time for the manganese sulphide to slowly rise up out of very hot iron, or that we can get a better mixing of the metal when indications point to a lack of perfect union of the several parts of the charge in running out of the cupola spout.

The further important lesson is that with the growing use of ferro-alloys these fine skins of oxidized metals are apt to remain in the molten metal and to defeat the very object of the additions, so far as strength of the resulting treated metal is concerned. Hence far better to devote every attention to proper mixing and melting, than to attempt to correct the product after it has passed from the cupola.

Your vice-president, Mr. Walter Wood, and your secretary, both being members of the International Committee on Testing Cast Iron and Specifications therefor, looked after the papers presented at the special session of the Congress for Cast Iron; Mr. Henry Souther, member of our Association, acted as chairman. Prof. Albert Sauveur, of Harvard University, acted as honorary secretary, looking after the French translation work, while your secretary was secretary of the session, as well as doing the German translating work, the Congress being carried on in three languages.

In addition to the work of the session, repeated conferences were had with the English and German representatives of the Congress with reference to specifications for pig iron, as well as the ever present test bar question. The summing up would seem to be that Germany has definitely adopted the chemical

idea for pig iron, as we have, England is slowly gravitating that way, though it may be a long time before this is an accomplished fact. There seem to be two conditions which retard progress. The first is the difficulty in certain English districts to get fairly uniform results with the blast furnace practice. The sulphur, for instance, due to variations in their ores, jumps about pretty lively during a cast. No doubt careful study of the situation will eliminate this to a great extent, once the foundrymen are in position to demand better service. In the meantime English export trade in pig iron is penalized about half a dollar a ton for just this reason.

The second difficulty is the subject of pig iron warrants. In storing pig iron it is so much easier to call it No. 1 or No. 2, in place of storing by analysis. The experience in this country would indicate that it is perfectly possible to store iron by analysis on warrants, hence here also it is simply a question of the good English blast furnace men waking up to the penalty they are paying in the world's markets, when export is the order of the day.

On the test bar question, England is glad to co-operate with us in the matter. They are still working on the attached coupon, the flat and heavy bar, and the matter of machining. Until the results clarify themselves and develop into definite lines, as they did first here, and then in Germany, little can be said, but there is the best of good feeling manifested, the underlying desire being to get at the truth, and how one can safest determine whether castings are satisfactory or not.

The papers covered a variety of subjects. Prof. Campbell and John Glassford have studied the effect of superheated steam on the constitution of cast iron, and found that while steel oxidizes only superficially when thus treated, cast iron suffers more seriously, the oxidation penetrating deeper, the silicon going first in a given spot, the graphite next, while the iron also oxidizes, damaging the material. Hence for valves, etc., it would be advisable to use iron with less graphite, between the flakes of which and the iron crystals the oxygen can enter.

Prof. Porter gave a paper reviewing the more important classes of castings and the service requirements of each, with recommendations as to the tests they should be subjected to. Mons. A. Damour discusses the physics of cast iron and recom-

mends tests which practically correspond to the ones we have here, as drawn up by our Association and the American Society for Testing Materials. Mr. J. E. Stead, the well-known English authority, discusses the test bar, and suggests that it be no shorter than 24 in. over supports, so that deflection measurements can be readily and accurately made. He finds that he can get sounder bars with the American and German standards than with the ones the English foundrymen are working on.

Prof. Charles Fremont presented an interesting method for testing cast iron. He takes a hollow drill, cores out a piece through the section of a casting, planes this core to a little half-inch square rod, puts it in a machine which shears off little pieces every half of an inch or so, and measures the force required to do this. By averaging these required pressures he gets an idea of the value of the metal in the casting. The little cubes of iron passed around the audience evoked considerable comment on the ingenuity of the method, but judgment on its value was suspended. Mr. J. Kail scored the grading of pig iron by fracture, and recommends classification of pig iron by analysis, giving the silicon composition of three suggested grades.

In the discussion by Walter Wood and others, this recommendation was deprecated, and it was pointed out that we in America were rapidly coming to the cutting out of all standards by grading or analysis. That each foundryman was beginning to make his own standards. He was setting up a composition, or series of compositions, which for his requirements were his standards. The work of associations then became the standardizing—if it may be called this—of the allowable variations which it was reasonable to assume would constitute good delivery on the part of the blast furnace man. So that a foundryman who specified so and so much silicon, or so and so much sulphur, would be safe in taking say 0.25 per cent either way for silicon, or anything below, but not above, the specified sulphur. This exposition of the situation seemed to be satisfactory to the assemblage, and the cause of exact working in the foundry as to the metal portion, was advanced just so much.

The paper by our member, Mr. Thomas D. West, on a suggested system of test bars for chillable iron was taken up, but being quite advanced in the art was left for individual study.

Finally a paper by the secretary on the tendency to push things too far in specifications was commented on, and the scathing denunciation of selling castings at high prices under names to catch the uninformed seemed to strike responsive chords among the assembly, and allusions to "semi-steel," and "gun iron from the cupola" were omitted after that.

The next Congress will be held in three years in St. Petersburg, Russia, and our American cast iron men were specially invited to come, and many have promised to be on hand at the time.

SOME SHORT CUTS IN THE FOUNDRY LABORATORY.

By P. A. Boeck, Worcester, Mass.

The function of the Works Laboratory in the development, control and improvement of manufactured products has long been recognized in certain lines of work, naturally those in which the laboratory has been instrumental in evolving new products or methods of manufacture. There is, however, in the present day of keen competition, a noticeable tendency for manufacturers to exercise closer supervision over the uniformity of materials which enter into their products, and also to check various steps in the manufacture, which is best done by means of various chemical and physical tests in the laboratory. Organized research is being conducted by numerous industrial plants for the purposes of obtaining at first hand all of the information possible relative to their product, with the idea of studying their methods of manufacture, eliminating waste and rejections and solving many of the problems brought up in every line of industry.

Research work,—special investigation or testing raw and finished products, as the case may be,—requires first a place suitably equipped for the special work which is to be conducted, and it is with some approved forms of apparatus with which this paper deals. Some of the appliances which will be mentioned have been developed in a research laboratory incidentally, in carrying out special investigations; other forms have been adapted from laboratories with modifications, and some may be familiar to you as routine apparatus. It is hoped, however, some new points will be brought out which will facilitate laboratory work in any line.

Electric Furnaces.

Until recently gas or gasoline was used almost entirely for the production of heat in the laboratory, but the advent of the

small electric furnace, with its ease of operation and regulation, cleanliness and facility, offers so many advantages over the other methods that it is becoming more and more widely used for general analytical work, heat treatment of metals, determination of melting points of metals, alloys, clays and other materials, for the determination of carbon in iron, steel, and similar lines of work.

It is generally supposed by those unfamiliar (or too familiar) with the performances of small electric furnaces that they are costly, both as regards installation and operation, and require considerable care and skill in operating and repairing. This, however, is not the case, for if a few fundamental rules are kept in mind the electric furnace will be found to be a great help, increasing the capacity, and in a great many cases, the accuracy, of many laboratory operations. The importance of the utilization of the proper temperature for laboratory work has been brought out strongly in two papers by Professor Theodore W. Richards, of Harvard University, before the Eighth International Congress of Applied Chemistry (Volume I, pages 403 and 411), the first on the "Control of Temperature in the Operations of Analytical Chemistry," the other on "The Measurement of Temperature in the Operations of Analytical Chemistry."

Any of the furnaces which will be described can be readily constructed in any laboratory at small expense and with little skill, and if reasonably handled last indefinitely, or in case of an accidental burnout can be easily repaired in the laboratory, this being one of the features of their construction. These furnaces are in the first place practical. They have been in use for a considerable length of time in an industrial research laboratory where delays and hindrances incident to burnouts and faulty construction would not be tolerated, and further, where an elaborate or complicated equipment was not available. They may be used on any 110-volt lighting circuit without other special equipment than a rheostat of simple construction and occasionally an ammeter to observe the flow of current.

The small electric muffle furnace shown in this illustration is designed for general laboratory work to take the place of the old style gas burner, for igniting precipitates, ashing coals, for heat-treating metals and the determination of the recalescence

and decalescence in steels, and similar work. It can be plugged in on any lamp socket, either with or without a rheostat,—one, however, being preferable for regulation of temperature.

This furnace consists essentially of a cylindrical core or muffle, around which the resistor is wound, about 2 in. in diameter and 2½ in. deep, made of Alundum, a highly refractory, chemically inert material consisting of fused alumina. This material has a very high thermal conductivity which conducts the heat from the resistor or heating element wound about its exterior

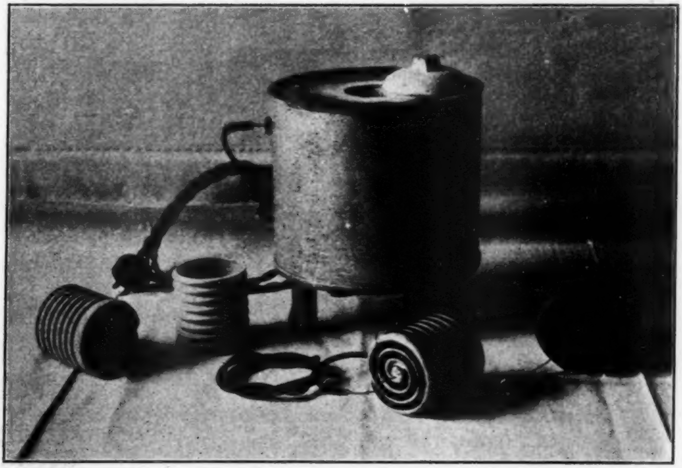


FIG. 1.—ROUND MUFFLE FURNACE SHOWING EXTRA CORES AND COILS.

to the center of the furnace rapidly and without loss, thus not only giving a highly efficient furnace but also preventing the heating element from becoming overheated and causing a burnout. It further has the property of being highly resistant to any slagging action or corrosion, which suits it admirably to the construction of small electric furnaces in which the resistor is of a metallic nature.

The heating element of this furnace consists of an alloy of nickel and chromium known as Nichrome, which has been found, by virtue of its refractory nature being resistant to oxidation,

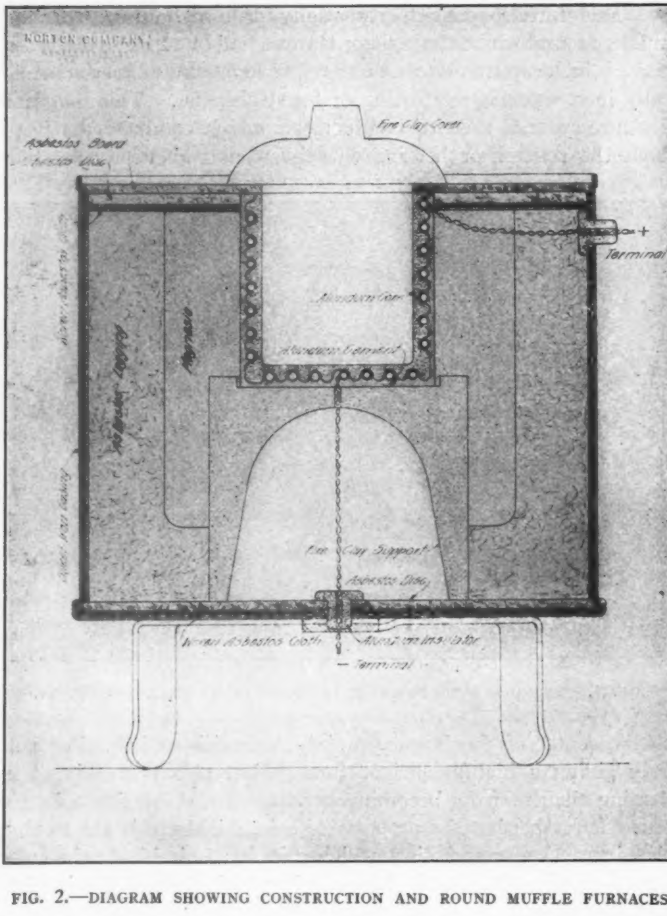


FIG. 2.—DIAGRAM SHOWING CONSTRUCTION AND ROUND MUFFLE FURNACES

high temperature coefficient and inactivity, admirably suited to the construction of furnaces of this type. This resistor, consisting of forty feet of No. 20 gauge wire, is wound in the form of a helical spring on a $\frac{3}{32}$ in. mandrel, one foot of the wire at either end being unwound and doubled to act as terminals. The coiled resistor is stretched slightly to prevent any two sections of the wire from being in contact, and is wound about the corrugations of the refractory core, being held in place by inserting the terminals through small holes in the core. The resistor and core are then covered to a depth of about $\frac{1}{16}$ of an inch with Alundum cement, which burns sufficiently hard, when the current is passed through the core, to hold the resistor in place and prevent any oxidation or short circuit of the resistor. By insulating the wound core by means of pipe lagging and magnesia (as is shown in the diagram) and incasing the hole in a sheet metal box of pipe lagging and magnesia (as is shown in the diagram), a furnace is obtained which will run continuously at 1000° C. (or about 1850° F.) indefinitely or even at a temperature up to 1100° C. (or about 2000° F.) for a short interval of time without any danger of a burnout. The energy consumption at this temperature is about 325 watts.

It is of course assumed that there will be no great variation in the line voltage of the circuit on which this furnace is used and particularly no fluctuation above 110 to 115 volts. A higher voltage would be above that for which this furnace is designed and as more energy would be forced into the furnace, without appreciably greater dissipation, the resistor, being heated to its melting point, would burn out. This, however, would not be a serious matter as the core might be readily rewound with another resistor and again coated with cement at a very slight cost. It can be safely said that nine out of every ten burnouts of electric furnaces is caused by the voltage for which the furnace was wound, being exceeded.

For most laboratory operations, with the possible exception of the ignition of alumina and silica, a temperature from 1000° C. (1850° F.) to 1100° C. (2000° F.) is ample and for this reason it is desirable that the temperature be controlled by means of a small hand rheostat which will undoubtedly add life to the furnace and enable it to be used more efficiently for a greater number

of operations than if no rheostat is employed. For the ignition of precipitates of the nature of alumina and silica, investigations have lately been undertaken to estimate the minimum temperature at which these precipitated materials burn to constant weight. Sufficient information has been obtained at the present writing to indicate that in a great many determinations the values for both of these materials have been high, due to the fact that they have not been heated sufficiently to drive off the water, introducing serious errors into the results of the analysis.

Carbon Combustion Furnace. For the direct combustion

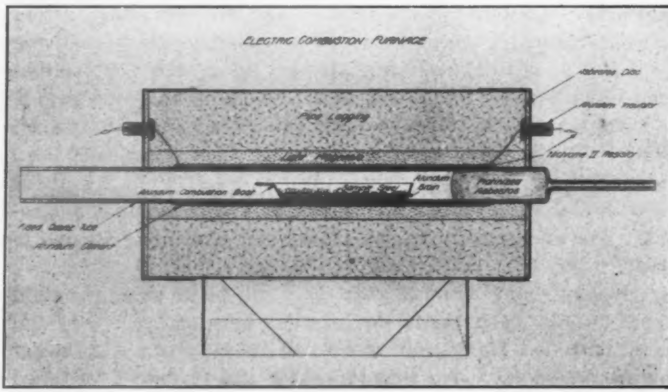


FIG. 3.—ELECTRIC COMBUSTION FURNACE SHOWING DETAILS OF CONSTRUCTION.

of carbon in iron and steel, electric combustion furnaces constructed as shown in the following diagram have been found to give very satisfactory results, in being accurate, rapid, easily controlled and readily constructed. A tube of fused quartz of $\frac{3}{4}$ in. bore and 18 in. long, one end of which is drawn out into a small tube having a bore of about $\frac{1}{16}$ of an inch, is wound with 30 ft. of Nichrome 2 tape .014 in. thick by .045 in. in width, as closely as possible, covering 8 in. of the central portion of the tube. This resistor has its two ends doubled for terminals as in the preceding case. It is covered with Alundum cement to hold the coil in place and to prevent oxidation and corrosion of the resistor, this in turn is surrounded by magnesia and pipe lagging for insulation

and the whole incased in a sheet iron box of suitable proportions. The interior of the combustion furnace will maintain a temperature of from 900° to 1050° C. (1625° to 1922° F.) for months without deterioration, providing a rheostat is used for the control of the temperature. The temperature of the combustion of carbon in steels and alloys has been the subject of extended investigations, the conclusions being that for ordinary carbon steels the combustion in an atmosphere of oxygen can be carried out completely at a temperature of 950° C. (1742° F.) and that most alloy steels require a temperature of from 1000° C. to 1050° C. (1832 to 1922° F.) Where a variety of materials is being used it is preferable to wind the furnace with slightly less wire, thus increasing the temperature, and regulating the furnace to the exact temperature desired by means of a small rheostat: The furnace consumes 300 watts at a temperature of 1000° C. (1850° F.)

In making direct combustions of carbon in steel it has been found that Alundum combustion boats consisting essentially of alumina do not react with the oxides formed and are so highly refractory under ordinary conditions as to permit of their repeated use. Where relatively high temperatures are used for combustion work it has been found desirable that a layer of Alundum grain especially calcined and free from carbon, be spread upon the bottom of the boat to prevent the melted oxides from adhering to the boat mechanically. Records have been obtained of as many as 212 combustions of carbon in steel having been made in a single boat where Alundum is used as a protecting medium. This reduces the coat of the boat and the Alundum grain to a ridiculously low figure and further this arrangement does not require any previous preparations or ignition to free it from carbon, as special care is exercised to remove all carbon from the Alundum grain before it is sent out.

Another advantage of Alundum combustion boats in the analysis of iron and steel is that they are porous and may be used for the filtration and separation of total carbon from the solution in the double chloride method by being placed in a suitable rubber block and the double chloride solution containing the carbon filtered through the bottom of the boat by means of suction. It may then be dried and the carbon checked by combustion in the usual manner. The advantages of the Alundum boats for this

operation are that they require absolutely no previous preparation and the filtration may be carried out by means of a strong suction with extreme rapidity.

In laboratories making routine analyses of highly silicious materials such as clays, sands and similar products, considerable care is required in driving off the silica by means of hydrofluoric acid to prevent "bumping," "spitting" and mechanical loss of the contents of the crucible. This is prevented by carrying out the volatilization with hydrofluoric acid in an electric furnace in which the crucibles are heated from the sides and top rather than from the bottom. At a temperature of 300° C. (572° F.) this action takes place rapidly and without any violent action. The furnace here shown was designed for this purpose and consists of an Alundum hemisphere, about 4 in. in diameter wound with 35 ft. of No. 20 gauge Nichrome 2 wire and coating the core and wire with Alundum cement to hold the resistor in place. The core is then suitably insulated with pipe lagging and incased in a sheet-iron box. The crucibles are supported on a wire grid which prevents them from coming in contact with the more highly heated portions of the core. This furnace consumes about 400 watts.

A small muffle furnace suitable for the ignition of coal samples, volatilization of ammonia salts from potash, or sodium determinations and similar work can be made by winding an Alundum muffle 3 in. high, $4\frac{1}{4}$ in. wide and 10 in. long with 70 ft. of Nichrome 2 wire No. 17 gauge. The outside of the muffle is coated with Alundum cement insulated and placed in the sheet-iron container such as has been shown.

All of the furnaces which have been described deal with temperatures not over 1100° C. (or 2000° F.) for analytical work or heat treating. These temperatures are easily obtained and introduce no particular difficulty as far as the maintenance of either the resistor or the refractory is concerned. When the temperatures rise above this point, however, trouble is usually encountered in having the heating element stand the temperatures and recourse must be made either to the platinum metals, carbon, or to tungsten or molybdenum and metals of a similar nature which require an atmosphere of hydrogen to prevent their being oxidized. The latter forms of furnaces, however, are employed only for the more intricate laboratory investigations and require

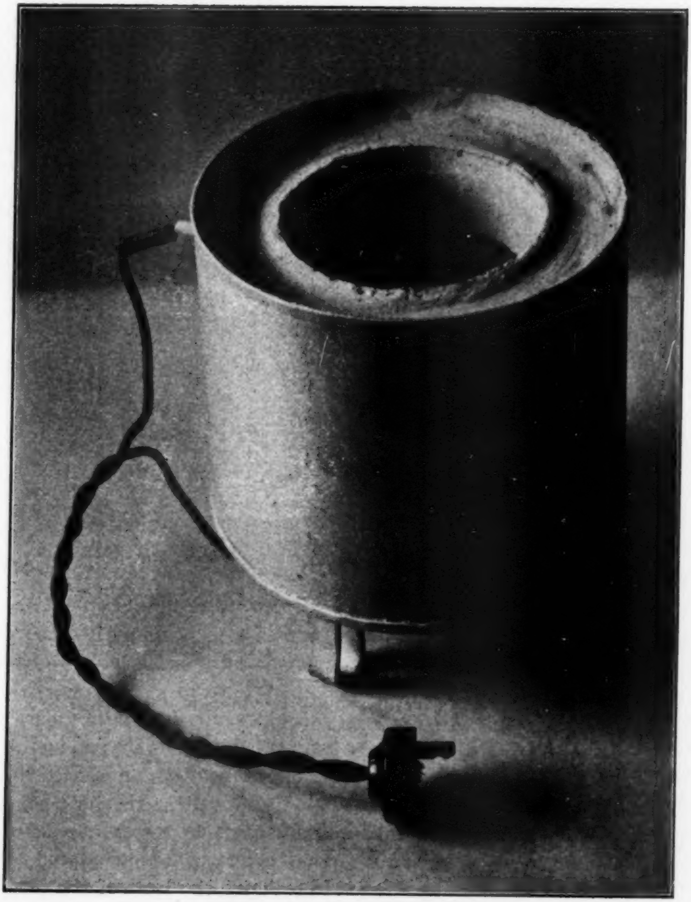


FIG. 4.—HYDROFLUORIC ACID FURNACE.

too much equipment and skill in operation to be given further detailed consideration here.

The main objections to furnaces having platinum resistors are in the initial high cost of the furnace and in the volatilization of the metal itself which is caused by forcing the temperature of the wire to a point considerably above the temperature desired in the furnace. This latter trouble is due principally to the fact that the resistor must necessarily supply all the heat lost by radiation from the outside of the furnace. This objection may, however,

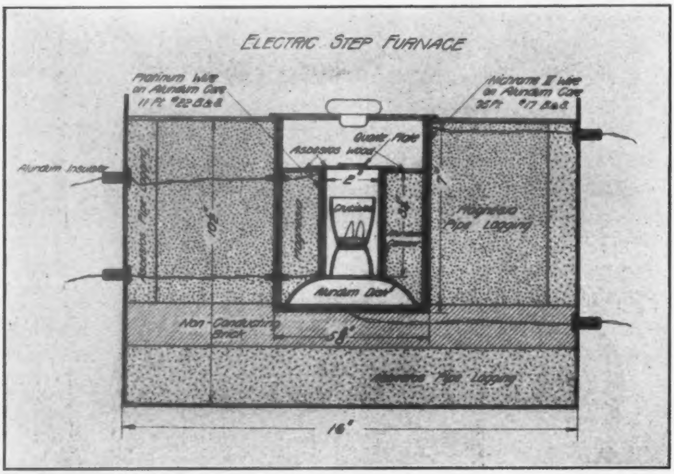


FIG. 5.—DIAGRAM OF STEP FURNACE.

be obviated by introducing a heating element of base metal, designed to take care of the heat radiated from the outside of the furnace and which need not necessarily be run at the high temperature desired in the furnace, and placing another resistor of platinum inside of this. All of the heat which is generated by the platinum core will be utilized in bringing the heat of the interior of the furnace up to the required temperature without the necessity of raising the temperature of the platinum resistor much above that of the interior of the furnace.

This idea has been embodied in the furnace described in the

following illustration. An Alundum core 5 in. in diameter and 7 in. deep is wound with the resistor, consisting of 70 ft. of No. 17 gauge Nichrome 2 wire and coated with Alundum cement, suitably insulated by means of pipe lagging and magnesia. Inside of this core is placed an inverted Alundum dish upon which a somewhat smaller core of Alundum wound with 11 ft. of No. 22 gauge platinum wire rests. This is also coated with Alundum cement to prevent fluxing. A baffle is placed over the top of the inner core to prevent the loss of any great amount of heat and over this a transparent quartz plate permitting of observation of the inside of the furnace without removing the cover and consequent loss of heat. The space between the outside of the platinum core and the inside of the Nichrome core is filled with loose magnesia to prevent any great loss of heat from the platinum core and also to prevent the Nichrome core from being heated to its melting point.

From 3 to 4 amperes at 110 volts are passed through the outside of the Nichrome core, producing a temperature of about 800° C. (1472° F.) A current of 300 to 400 watts independent of that passing through the Nichrome core is passed through the platinum core, from 5 to 7 amperes being consumed which is suitably regulated by means of a water rheostat. Practically all of the energy passed into the platinum core is transformed into heat which is retained in the interior of the furnace, temperatures up to 1400° C. (2552° F.) may be quickly produced and indefinitely maintained. A furnace of this type has been in operation now for several months for determining the melting point of ceramic bodies below 1400° C. and no trouble has yet been experienced from burnouts.

The main idea in this furnace is, briefly, to produce a temperature of 1400° C. or less by means of two cores, one inside of the other, the outer taking care of the heat lost by radiation and conduction and the inner one being depended upon entirely to heat the interior of the furnace.

Carbon Resistance Furnace.

For obtaining temperatures as high as 1800° C. (3272° F.) recourse must be had to carbon as a resistor. This material has a very low electrical resistance and a large temperature coeffi-

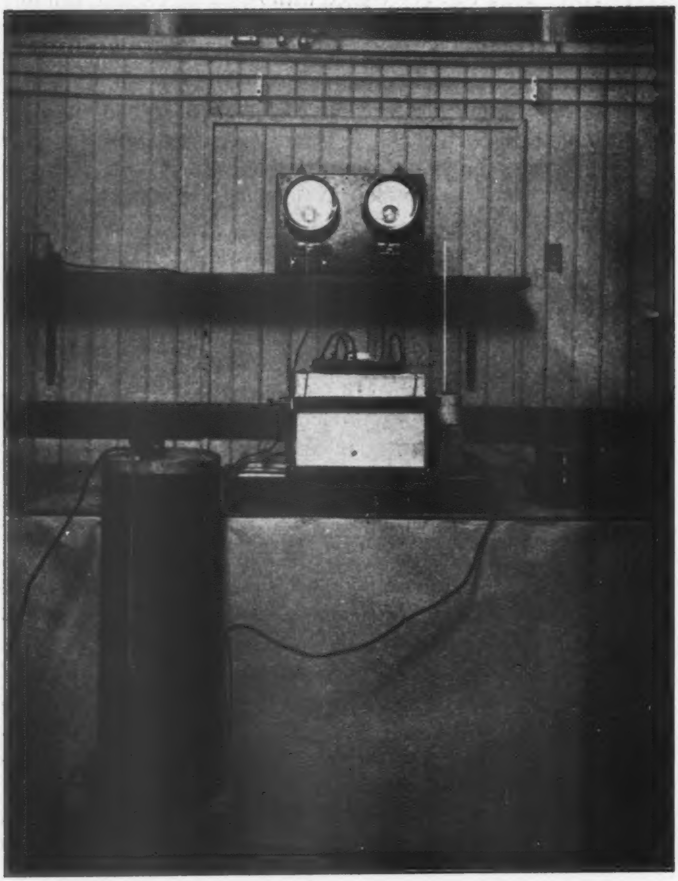


FIG. 6.—CALHANE FURNACE IN OPERATION.

cient, so that, in general, the wattage energy or heating effect of the current is attained by a large current volume on low voltage.

A furnace which has been used successfully for a variety of purposes such as melting refractory materials, alloys, platinum, etc., has been designed by Dr. D. F. Calhane and described in *Metallurgical and Chemical Engineering*, Vol. 10, No. 8, page 461. In this furnace the resistor consists of granular carbon placed

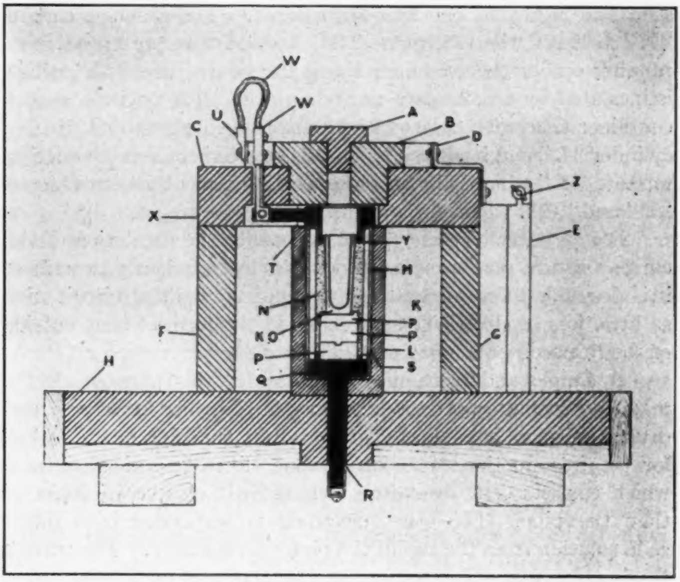


FIG. 7.—DIAGRAM OF CONSTRUCTION OF CALHANE FURNACE.

between two carbon rings which act as electrodes. The carbon resistor is held in place on the outside by an Alundum tube, on the inside by walls of a highly refractory Alundum crucible. By passing the current through the carbon resistor the temperature of the resistor together with that of the crucible is raised. A temperature of melting platinum can be obtained in approximately 50 minutes starting with the cold furnace with an expenditure of about one K. W., the voltage at this temperature being approxi-

mately 70 and the amperage 15. This type of furnace is extremely valuable in the determination of the melting points of metals, alloys, refractories and materials of a like nature. The only disadvantage being in its strongly reducing action.

The black portions at the top and bottom of the core marked respectively "R" and "Y" are graphite electrodes between which the granular carbon resistor marked "N" is compressed. The Alundum crucible "O" is supported on Alundum blocks marked "P" and is heated by the resistor "N". The granular carbon "N" between the electrodes "R" and "Y" is prevented from running out of the container by an Alundum tube "M" which is insulated by an air space on the outside. The entire core and container tube with the electrodes are held in place by a fireclay cylinder "L" and insulated by an asbestos cement non-conducting mixture "K" which is in turn insulated by cement asbestos blocks "F" and "G".

For furnaces of this type as well as for the regulation of the current in the platinum resistance furnace previously described, it is desirable to cut down the voltage of the lighting circuit with as little loss of electricity as possible in the form of heat outside of the furnace.

A simple and convenient rheostat for this purpose can be made by sealing up the bell of an 8 in. vitrified sewerpipe and drilling a small hole through the wall of the pipe near the bell for the introduction of a wire to one electrode inside the pipe which consists of a sheet iron cone slightly smaller in diameter than the pipe. The other electrode is suspended in a dilute soda solution from the top of the pipe over a pulley. The current flowing is regulated by varying the distance between the electrodes.

Aside from the refractory properties of the Alundum articles which have been mentioned, namely: melting point which is in the vicinity of 2000° C. or about 3600° F., a thermal conductivity much higher than either fire clay or porcelain, a non-conductor of electricity even at elevated temperatures, chemically inactive toward fluxes, it has also been found to possess sufficient porosity when made up into various shapes to allow of its being used as a filtering medium for a variety of purposes. A few words as to the manufacture and nature of these articles may be of interest in this connection.

Alundum, the material from which these articles are made, is the product of the fusion of the mineral bauxite (a natural hydrate of alumina carrying small percentages of iron oxide, silica and titanium oxide) in the electric furnace, in which process partial purification takes place so that the resulting product is essemtially pure fused alumina.

This material has been used quite extensively for abrasive purposes, replacing emery and corundum, over which it has the advantage of being absolutely uniform and of easily controlled composition. It can be made to yield an abrasive higher in crystalline alumina and consequently of higher abrasive efficiency than any other form of commercial, natural aluminous abrasive.

In the manufacture of laboratory articles of this material, the fused alumina is crushed, graded to uniform mesh, mixed with a small amount of suitable ceramic bonding material and burned at a high temperature in an ordinary porcelain kiln, where the bond is caused to vitrify or mature, giving it the strength of an ordinary porcelain body, and at the same time retaining its porous nature, which allows the penetration and filtration of liquids and gases.

The porosity of the bodies can be controlled in several ways which depend, to a certain extent, on the other physical properties, such as strength, thermal conductivity, texture, melting point, expansion due to temperature changes, shrinkage, etc., that may be desired. The three methods most generally used in obtaining bodies of different porosities are:

1. By varying the size of the grain or particles of the Alundum, thereby changing the size of the voids;
2. By changing the kind; and
3. The amount of bonding materials used.

By combining these factors, suitable bodies may be obtained having any texture or porosity required for the penetration of liquids of any density. The state of subdivision of the residue which is to be separated from the liquid or gas is of course the final criterion of the permissible size of the voids. In organic extraction work it is particularly desirable to have a porous medium, which gives the most rapid filtration possible with the complete retention of the residue.

FIG. 8.—ALUNDUM FILTERING CRUCIBLE IN OPERATION.

Advantage has been taken of the porous nature of crucibles made of bonded Alundum to adapt them to the filtration of precipitates from solutions in quantitative analytical work by the aid of suction in the same manner as asbestos lined Gooch crucibles are used. As the walls of the Alundum crucibles themselves act as the filtering medium, however, it is not necessary to prepare them in any way before use, and by forcing water or dilute acid solutions through the crucibles in the reverse direction they can be readily cleaned and brought to constant weight by ignition for further work.

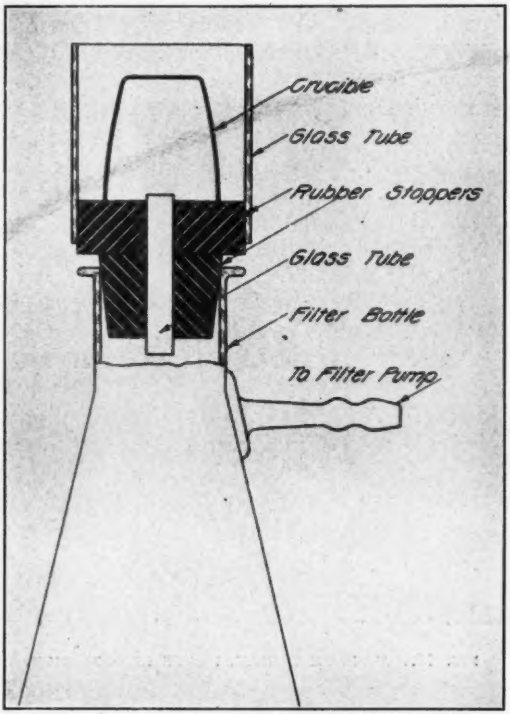


FIG. 9.—APPARATUS FOR CLEANING ALUNDUM FILTERS.

The time saved by the use of suction in filtering operations is so great that it cannot be ignored in the busy laboratory. The use of the crucible filter, however, has one or two disadvantages which we believe have been overcome in the later form of cone filter which has just been perfected. Soluble salts in the solution being filtered have been found to be drawn into the upper portion

FIG. 10.—ALUNDUM CONICAL FILTER IN OPERATION.

of the crucible above the filtering area and lodging there are washed out only with extreme difficulty.

The new form of filter in the shape of a hollow porous Alundum cone of 60 deg. angle, to fit any ordinary funnel, is held in place by means of a wide rubber band about the top of the funnel. The more the suction applied, the tighter the joint between the filter and the funnel becomes. It will be seen that all of the surface of the cone is engaged in active filtering and capable of being

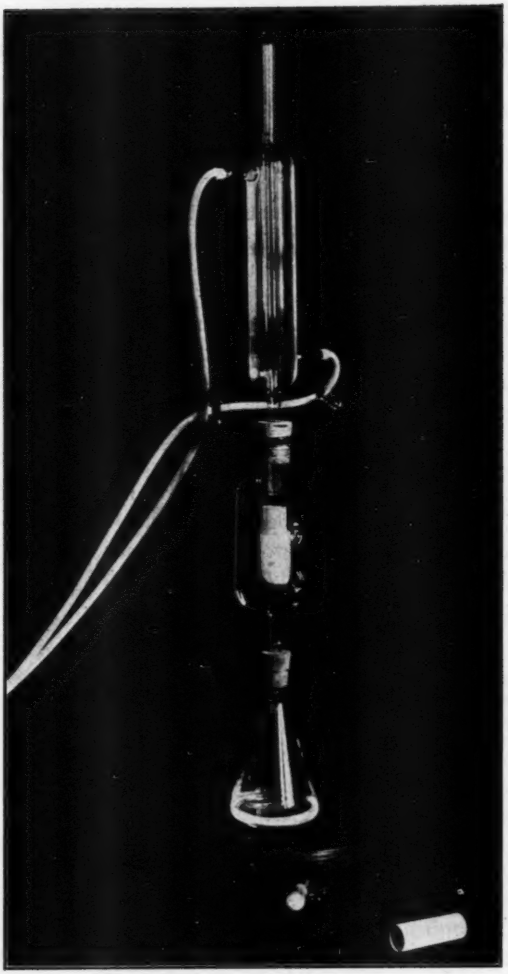


FIG. 11.—EXTRACTION THIMBLE IN OPERATION.

washed, leaving no place for dissolved salts to deposit. The filtering area too has been increased to a maximum. For very careful work where double precautions are desirable it is possible to use an ashless filter paper inside of the filtering cone, but a slight decrease in the rapidity of filtration results.

Such precipitates as phospho-molybdate or magnesium phosphate are filtered with extreme rapidity and offer one of the principal methods for time saving in the metallurgical laboratory.

In organic work it is particularly desirable to have a porous extraction thimble which will allow of the most rapid filtration possible with the complete retention of the residue. A feature of aluminum extraction thimbles lies in the fact that no blank extractions are necessary to be sure that the materials are fat free as is the case with paper thimbles. Being of a refractory nature the Alundum article can be readily and completely cleaned by ignition at a temperature high enough to dispel any organic material. This also allows of their repeated and indefinite use so long as no easily fusible inorganic material is ignited in them.

For standardizing thermocouples by the melting and freezing points of pure metals it has been found that Alundum crucibles are admirably adapted to this work in being inactive and allowing the metal to be used repeatedly without danger of errors due to contamination.

SUGGESTIONS FOR PREVENTING FOUNDRY ACCIDENTS.

By W. H. Cameron, Chicago, Ill.

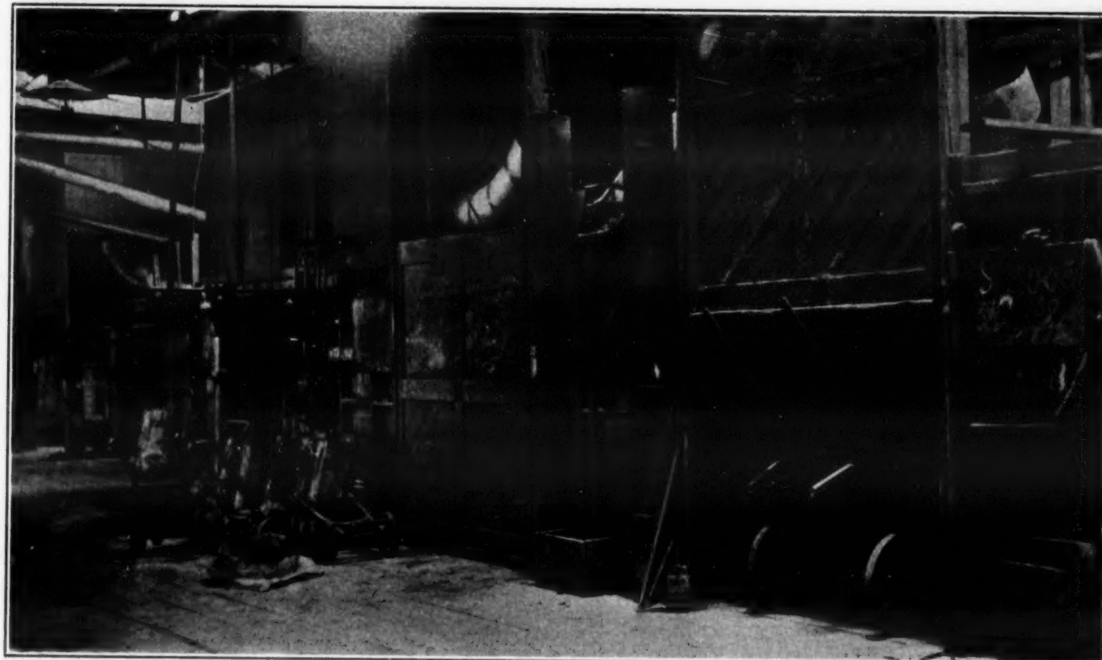
The "Prevention of Accidents" is an intricate and far-reaching subject. Injuries to workmen affect, directly and indirectly, every citizen, as well as the state and the nation. Many and varied estimates of man's value have been made. Statisticians reckon the average man's value at $600 per year. Each worker in iron or steel stands for an engine or industrial plant worth $10,000, producing at 6 per cent an income of $600. The death of the average workman, therefore, is equivalent to the destruction of a $10,000 mill or engine. The legislative tendencies of recent years have been to place the entire liability for these accidents upon the employers, and the problem of meeting this responsibility is an exceedingly serious one. The desiderata are not simply to safeguard machines and working conditions, but to know how to protect workmen against themselves. It is well known that the workman's carelessness breaks delicate machinery; his ignorance spoils raw material; his idleness blows up boilers; his recklessness destroys engines, and he is just as thoughtless of his fellow-workmen's safety as his own. In a word, the most difficult phase of the subject is to know how to wake up the employee to a sense of his duty towards himself and his fellow-workers, and assist in the prevention of accidents. The evangelist's attitude towards his lost brother must be the attitude of the employer towards his employee in the furtherance of the safety propaganda—"He must preach it; sing it; and pray for it."

There is a grimness about the statistics of injuries and fatalities among industrial workmen that is appalling. The records show that thirty to thirty-five thousand wage earners die from work accidents in the United States every year. There are some eighty thousand people in the United States, who, through often unnecessary blindness, have become social liabilities instead of

assets. Approximately two million men are seriously injured every year. It would be difficult to imagine the amount of suffering and distress these accidents bring upon the sufferers and families dependent upon them. In a recent year these casualties cost twenty-two million dollars of money in employers' liability insurance premiums alone. This has been the cost to the employer for protection, but as probably not more than 25 per cent of this amount has reached the sufferers, it is easy to understand the attitude of the workers, and the social agencies behind them, to recover larger and more adequate compensation. We are, therefore, face to face with the question of how to prevent accidents, and reduce the suffering and deprivation which these losses entail upon the workmen, and their employers, as well as upon society as a whole. The accidents caused by negligence are largely preventable. The means of prevention lie in the direction of (1) proper design and construction of plant and appliances (2) co-operation on the part of employers and employees, and (3) the use of safety devices. Although considerable stress will be laid in this paper upon the proper design and installation of protective devices, it is believed that at least two-thirds of the accidents which happen in any plant are due to carelessness on the part of the worker, and negligence for which the employer and employee are responsible.

It is an easy matter nowadays to secure information from the current journals of the details of organization for carrying out elaborate plans for safeguarding employees, involving the expenditure of large sums of money, but while it is believed that the underlying principles of both large and small organizations are essentially the same, it will be the intention of the author of this paper to define the experience of one of the smaller corporations in its efforts to prevent accidents and protect its workmen to the maximum.

Up to two years ago the American Steel Foundries followed the usual custom of protecting itself from money losses due to accidents under employers' liability policies. Investigations were made several times with a view to ascertaining the probable cost and risk of carrying its own insurance, but on account of the hazardous character of its work, the insurance was continued until it came to the realization of the economies of safeguarding. It



STEEL PLATE GUARDS ENCLOSING DOOR COUNTERWEIGHTS. SAND BLAST HOUSES.

then became apparent that the company could control, to some extent at least, the frequency of accidents among its employees, and this assumption has been borne out by actual experiences. As in other pioneer work, the simplest method was first followed. A general inspection was made of the buildings and equipment at the plants, and recommendations made for the installation of safeguards at the most dangerous places. When these recommendations were approved the master mechanics at each plant were asked by the managers to supervise the making and installation of the guards, and report monthly the necessity, if any, for additional guards. This method was only partially successful. The master mechanics were busy men, and more or less calloused by frequent contact with carelessness and indifference on the part of the workmen. It was also observed that the initial efforts to protect the men were not received kindly, and it seemed futile to foist upon them what they would have looked upon as handicaps in their work.

The next step in the furtherance of safety work was the appointment of workingmen's and foremen's committees. Three men were selected from three different departments of the plant, and instructed to make four whole-day inspections during the month. Men were selected who were not only old employees and familiar with all parts of the plant, but who were known to be conscientious and not afraid to report what they saw. These men were carefully instructed in their work, and informed that the company did not obligate itself to accept any of the suggestions, or do any work. They were paid full wages while engaged on their inspection duties, and $5 each upon presentation of their reports at the end of the month.

These workingmen's committees revealed the immense possibilities at each plant for safeguarding. We received during the first month in all about one thousand suggestions, and at two of the larger plants approximately three hundred each. These recommendations were described carefully in writing and numbered consecutively, and submitted to the three foremen in charge of the departments from which the men were selected, and they acted as a jury in approving or disapproving the suggestions made. The jury of foremen visited and inspected all of the dangerous conditions pointed out by the workingmen's committee, to be in a

HORIZONTAL BARS ON BRACKETS IN FRONT OF REVOLVING RUMBLERS; ALSO GUARD RAILINGS ENCLOSING DRIVE BELTS AND PULLEYS.

position to say "Yes" or "No" to the recommendations. Only a small percentage of the suggestions were rejected as impracticable. The combined report of the workingmen's and foremen's committees were then submitted to the plant managers, and they expressed their opinion of the reports. The result of the careful consideration of each recommendation from three different standpoints was a warranty to the officials of the company that the final recommendations were probably worthy of acceptance. These committees were continued during the following month, and with about the same result. They were then discontinued for the reason that each plant had so much work to do that it seemed impracticable to pursue the subject further until the recommendations already made had been carried out. Since then, however, similar workingmen's committees have been appointed with continued good results, and it is believed that the workmen in the plants, familiar with every working condition and having the interest of their self-protection in view, can be as productive as any other agency in calling attention to the hazards of the industry. By changing the committees monthly the attention of a number of workmen will be in time especially directed to the subject of safety, and this nucleus will help to leaven the lump of the disinterested mass of workers.

The next step in our experience was to find a means of following up the work satisfactorily, and at five plants employing approximately 1,700, 1,200, 900, 800 and 500 workmen, safety inspectors have been engaged to devote all of their time and efforts to the safety work, including the inspection of machinery or equipment for broken or worn-out parts, the continued use of which may cause an accident, such as flask trunnions and flanges; the inspection of buildings for loose bricks; pillars; boards and loose material stored overhead; cranes and crane runaways for loose parts; use of gongs on cranes; improper riding of workmen on loads being carried by cranes; also to be on the lookout for slippery places on floors and stairways; holes; broken boards and protruding nails in boards. To make regular inspection of railroad tracks for guards at frogs and switches; holes about tracks; piling of materials too close to tracks; riding on engines and cars without permission, as well as hoisting cables for broken strands and rust. To oversee the use of scaffolding for painting

SERIES OF THIRTEEN KNUCKLE AND LIFTER GRINDERS SHOWING STEEL PLATE AND WIRE SCREEN BELT GUARDS; HOODS ENCLOSING WHEELS AND SAFETY COLLARS; ALSO STEEL BRADED APRON AND SAFETY SPECTACLES USED BY GRINDERS.

or making other repairs. The use of congress shoes by foundrymen; leather leggings by oilers and repairers; rawhide gloves by laborers handling rough materials; wooden-soled shoes by men repairing furnaces, and to be on the lookout for loose sleeves while operating machinery. To inspect for the proper and constant use of safeguards. To report narrow escapes from injury, and the causes therefor, and to recommend discipline for workmen or recommendations for additional protection, as well as to report all other conditions about the plant which might be considered hazardous and likely to result in injury to workmen or damage to the company's property. These inspectors are required to attend all meetings of foremen, to call attention to unsafe conditions about the plant, and to suggest improvements in the method of handling work from a safety standpoint.

A committee of three foremen at each plant submits reports of serious accidents, and causes therefor, at the meetings of the foremen and the heads of the departments. These reports are discussed and recommendations made for the prevention of similar accidents. One of the corollary advantages gained by this committee work is the impression made over and over again upon the minds of all of the foremen of the importance of adopting the safest methods possible in having work done. It is true, however, that the burden of stimulating the foremen and heads of departments rests almost entirely upon the management of the plant. It is believed that the foremen more than any other agency in the plant can bring about a diminution in accidents. The attitude of the foremen toward the prevention of accidents will be reflected by the workmen just as accurately as their attitude toward the production of castings is reflected. If the manager treats the subject lightly, his assistants will look upon it in the same way. If he shows a determined desire to avoid accidents, and insists upon the rules of the plant being obeyed; if he is determined to make the prevention of accidents one of the most important features of his department, then the foreman will insist upon the men taking the precautions which are known to be necessary for the prevention of accidents. It should also be the foreman's duty to instruct every new man in the hazards and dangers of his work, and whenever he observes unnecessary risks being taken to stop them at once, and if repeated, discharge the offenders.

Until the workmen understand from the foremen that "safety first" must be their motto, and that accident prevention is one of their first duties, it is believed that accidents will continue in the same ratio as in the past. It is better to prevent an accident and

BELTMAN SHOWING LEATHER LEGGINGS TO PREVENT TROUSER LEGS GETTING CAUGHT IN MACHINERY, AND PADLOCK TO LOCK UP SWITCH-BOXES WHILE AT WORK ON MACHINERY.

keep an experienced man at work than to cause a disturbance in the organization by breaking in a new man. There is no more difficult phase of promoting safety principles among foremen and workmen than to make both classes understand that the old care-

less and reckless habits must be replaced by education in safe methods.

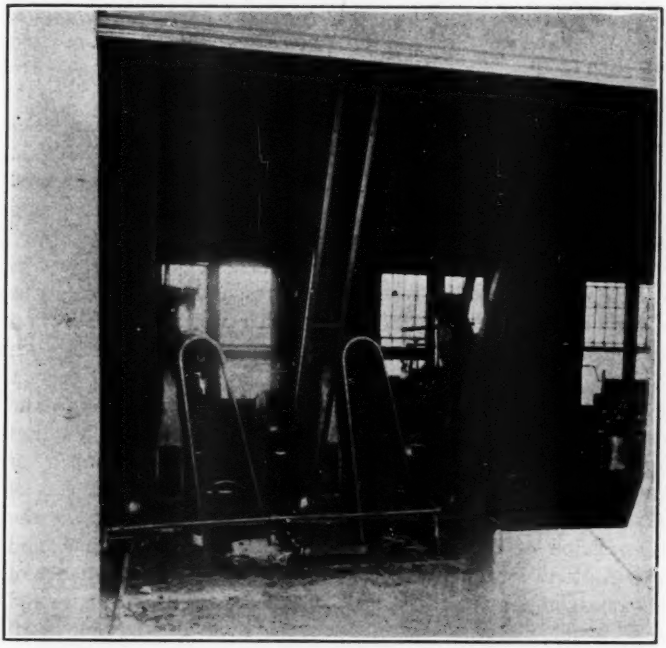
The results of the workingmen's committee's investigations were forwarded to the central office of the company, and all of the plants have received the benefit of the recommendations made. The central office keeps in constant touch with the inspectors on safety matters, and when an accident occurs showing carelessness or unnecessary risks taken, or where the use of a safeguard would have avoided the accident, a sketch and safety bulletin is sent to all of the plants, with recommendations as to the avoidance of similar accidents. The central office also has charge of the care and compensation of all injured employees under a voluntary relief plan and the workmen's compensation laws; receives full reports of all accidents, and when it is apparent that repetition of such accidents can be avoided by cautionary measures, recommendations are made to all of the plants, so that each one receives the benefit of the experience of the other.

The organization of the safety work has, therefore, been conducted through the efforts of committees at each plant; a supervising safety inspector, and the general dissemination of the experience of all plants through a central office. In the smaller corporations, or even individual plants, this plan will be found effective and inexpensive. The safety inspector in a plant employing from six hundred to eight hundred workmen will have ample time to attend to the full investigation of all accidents; the preparation of all reports, as well as to the visitation of injured workmen, and represent to them the interest of the company in their welfare and speedy recovery. He can also assist the company in reporting workmen who are inclined to magnify their injuries and make fictitious claims against their employers. We believe that these inspectors need not necessarily be experienced men in safety work. Suggestions and photographs of practical safeguards have been distributed so widely and liberally during the past year or two by such corporations as the United States Steel Corporation, International Harvester Company, American Museum of Safety, and others, that a fairly intelligent young man can soon apply the data at his command to the conditions in the particular plant he represents.

My further remarks will be confined largely to the work which

has already been done by the American Steel Foundries for the prevention of accidents at its several plants.

As a preliminary to employment every applicant is physically examined by the company's surgeon to determine his fitness for work. As a result of experience in making these examinations "standards for rejection" have been adopted for the guidance of



STEEL WIRE SCREEN AND ANGLE GUARDS ENCLOSING EXPOSED HIGH SPEED BELTS AND DOORWAYS OF FORGE SHOP.

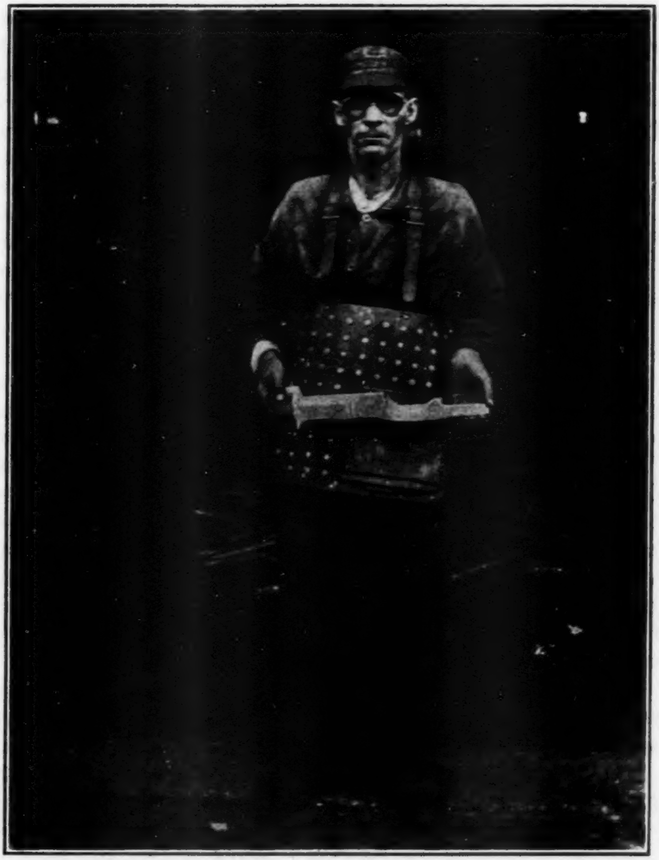
the surgeons, and if the applicant for employment is rejected by the surgeon, he is not permitted to go to work, unless the exigencies of the labor market are such that the applicants not seriously handicapped must be retained temporarily. A record of these rejected men is kept, and as soon as the labor conditions warrant it, they are the first to be laid off. At the larger plants of the

company, located at or near the large cities, the average rejections by the doctors has been 15 per cent. We have records of several accidents to men who have been rejected and retained. By making these examinations the company receives some assurance that its workmen are at least physically fit for their work, and they will not be saddled with claims for injuries which might be due primarily to weak hearts, ruptures, defective eyesight, serious condition of varicose veins, epilepsy, excessive use of intoxicating liquors, etc. When it is necessary to hire one of these physically impaired men, a release is secured to free the company from responsibility for such defect.

Probably 50 per cent of the accidents in steel foundries affect the eyes of workmen. Proper lighting is the first essential in the conservation of eyesight, but there are other dangers, such as careless use of emery wheels, flying metal chips, burns and other comparatively obvious eye accidents.

There are two essentials in the guarding of eyes: first, protection from foreign bodies reaching the eyes, and, second—and this is very important—protection from other workmen. The first consists mainly in the wearing of suitable goggles; and the second, the use of screens and instructing careless workmen to protect themselves. That this is not a small task has been proved by the experience of one steel corporation who testify to two hundred and fifty men who have lost their eyesight by permitting other workmen to remove foreign bodies from their eyes. The loss of sight in these cases results from perforation of the cornea; the transmission of infection by finger nails, or other means, and corneal ulcers forming large scars as a result. The experience of this one company teaches that workmen should be instructed never to allow anyone but a doctor to remove a particle from the eye.

An investigation of the use of spectacles and goggles by other industries revealed the fact that not one had been entirely successful in educating their workmen in the use of any style of spectacles. It was found, however, that the old-fashioned type of grandfather's glasses had more or less successfully protected the eyes of men working at emery wheels, and with these glasses as a foundation to build on, the spectacles now in use are worn by about 90 per cent of the men who should wear them, viz: machinists, sledgers,



SHOWING GRINDER'S OUTFIT. GOGGLES TO PROTECT EYES FROM STEEL CHIPS AND EMERY DUST. STEEL BRADED LEATHER APRON TO PROTECT ABDOMEN FROM VIBRATION OF EMERY WHEEL WHILE GRINDING CASTINGS.

floggers, chippers, and men working about scrap breakers and crushing machinery. The present design of spectacle is equipped with mesh screens at the sides and heavy lenses. The total weight is about one ounce per pair. A case is provided with each pair of spectacles, as well as an especially prepared cloth and paraffin pencil, used by automobilists to keep their glasses free from moisture and dirt. The complete outfit, including a spectacle case, costs about eighty cents. The spectacles are also recommended for workmen handling hot babbitt metal. Explosions have been known to scatter the metal into the eyes of workmen. Special lenses are suggested for ladlemen made of a combination Pugh (blue glass) and white glass. By this means the men secure a double use of the glasses; they can look at the metal through the blue glass, and use the lower part, made of white glass, in walking about the shop.

Men employed about electric welders should wear a helmet to cover the head. These helmets are made of aluminum or tin, and are so light in weight that the men are glad to wear them. The opening in the helmet to see through is covered by a set of four glasses, two red and two blue, arranged in the order of one blue and one red. This arrangement provides a quadruple protection against the intense rays of light. The arc welders' room should be isolated. The roof of this room will necessarily have to be open, and if, for instance, overhead cranes are allowed to pass in this vicinity, the cranemen will have their eyes affected in the same way as a welder without a helmet.

Workmen afflicted with eye trouble, such as near-sightedness, should have special lenses made and fitted to the safety spectacles to protect their eyesight and make the lenses comfortable.

The next problem was to have the glasses worn by such workmen as chippers and floggers—the majority of whom are foreigners—and it was found that these men would not voluntarily use the spectacles. An effort was then made by one of the plants to have the spectacles worn under the supervision of a watchman who had time to circulate among these workmen, and stimulate them in the use of the spectacles. Since the employment of safety inspectors this duty has been delegated to them. As an additional stimulus to wear the spectacles, every cleaning room workman was asked to sign a contract with the company, under the terms of which

he agreed to wear the spectacles constantly, and in the event of injury to his eyes happening while at work without spectacles, the company is absolutely freed from responsibility for the accident. It is believed that supervision and education along the lines described will have to be adopted in all foundries employing a large number of chippers and floggers, for the reason that these men will not protect themselves voluntarily, and the foremen and their assistants are usually too busy to give special attention to the use of spectacles. When a workman realizes that he cannot

PICTURE SHOWING CONTRAST WITH SHOE WORN BY WORKMAN, AND CONGRESS SHOE WORN BY FELLOW WORKMAN.

secure a job in the dangerous trades if he refuses to wear spectacles, the habit will soon become fixed and every employer will be benefited. The cost of the spectacles is infinitely less than paying compensation for the loss of eyes.

We have recently had a photograph made (32 in. by 20 in.) showing a collection of approximately one hundred pairs of spectacles, the lenses of which have been damaged by flying chips over a period of about three months. We have collected in six months two hundred and eighty-seven pairs of these spectacles with broken lenses. Forty-seven pairs of these spectacles were received from one plant in one month. Only three eyes have been

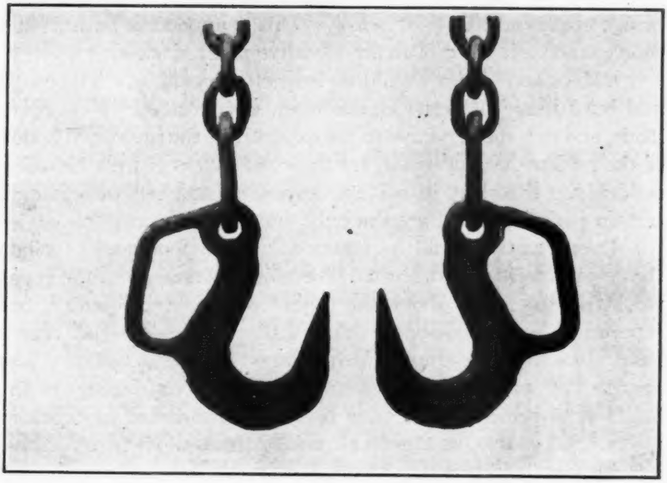
lost in all of the plants of the American Steel Foundries over a period of twenty-seven months by workmen using spectacles. In one instance the piece of steel penetrated the lense with great velocity, and entered the eye of the workman. We believe that if the spectacles had not been worn a much more serious accident would have resulted. The second eye accident happened to a machinist before we had insisted on the use of the spectacles by this class of workmen; and the third eye injured happened to a chipper who temporarily was carrying his spectacles in his pocket instead of wearing them.

Another means adopted by our company to protect workmen while cleaning castings, is to provide screens made of canvas, mounted on supports, to be placed between the men as they work. The screens have been effective in preventing flying chips from striking fellow-workmen, but they are not as complete a protection to the individual workman as the use of spectacles.

We also require emery wheels over eight inches in diameter to have a safety taper of three-quarters of an inch to the foot, and to be protected with safety collars. This means that the wheels will be convex in shape, while the collars will be concave, and should the emery wheel break in service, it being thicker at the hub than at the face, the pieces will be held together. All emery wheels are also protected with cast steel hoods with plates bolted at one side, and the emery wheels used by workmen grinding tools are provided with plate glass shields to protect the eyes. Care is also taken to keep tool rests closely adjusted to the wheels so that castings cannot be jammed between the wheels and rests. Exhaust systems are also recommended to prevent sparks and other particles from injuring the workman by being breathed into his lungs. Emery wheels often break through mistakes made by repairmen in not changing the speed limits when placing new wheels on spindles. Our safety inspectors are required to test the revolutions per minute of all emery wheels once per week, and check up the speed limits. Wheels are often run at speeds far too great for their diameters. The belts and pulleys of all emery wheels are also protected by metal guards.

Accidents occur in all foundries by feet being burned by slopping metal. It is very important that workmen wear whole shoes, and that they be so constructed that they may be slipped

off quickly. We urge upon our workmen the necessity for wearing congress shoes and buckskin leggings to fit over the tops of the shoes. We have undertaken to keep a stock of such shoes on hand at all plants, which are sold to the workmen at wholesale prices. The result is that the workman buys the shoes and protects himself from accident, and the company benefits by keeping the workman constantly at his job and by a reduction of the accident expense account. These shoes and other safeguards, such as



SAFETY CHAIN HOOKS AND HANDLES.

leggings, buckskin gloves, leather aprons, helmets, spectacles, respirators, etc., are exhibited in a cabinet close to the entrance of the plant so that the attention of all workmen will be called to them and stimulated to protect themselves.

All overhead cranes should be protected with walks on both bridge girders, extending the entire length of the crane. Each crane should be provided with a safety switch installed on the bridge, which will cut off all power, making it impossible for an absent-minded operator to forget that men are working above and start the machinery from the cab. Each crane should also be equipped with guards extending out from the truck wheels, the purpose being to warn any person who may be resting his hand

on the runway of the approach of the crane which he might fail to notice because of other noises. A number of accidents happen to men working on scaffolds or crane runways. A workman may rest his arm or leg thoughtlessly against the runway and fail to notice the approach of the crane, and be run over with the loss of an arm or leg.

All trolley gears and truck drive gears should be guarded. The trolley frame should be completely floored in, in order to prevent loose parts of trolley mechanism falling between crane bridge girders, to the floor below. This is important both from a safety standpoint and from an operative point of view.

Cables and chains should be inspected regularly. The rough and hard usage of crane chains often overstrained by excessive loads, and in some instances to the exposure of the prolonged action of the radiant heat of metal, are the chief causes of their breaking suddenly. Frequent inspection, annealing and renewals after a certain period of time, are the only safeguards against this.

Every crane should be equipped with a foot gong. When these gongs were first suggested objection was made that the gongs would not be heard above the other noises in the foundry, but experiment soon proved the value of the warning, and all cranes have since been equipped with gongs. These gongs are also guarded by wire nets to prevent the gongs from falling on the heads of workmen should they become disconnected or break in pieces. Of course, as a general part of the equipment of cranes, foot brakes should be provided, as well as boxes for oil cans and tools, so that the latter will not be laid around carelessly and fall on the heads of workmen.

Steel ladders should be provided to enable cranemen to reach their cranes safely. These ladders should be made of angle iron, not pipe.

Pattern Shops.

Band saws should have a hinged guard covering the top and front of the saw to prevent the saw flying should it break, and a head guard extended down from the saw to prevent the workman's head from accidentally coming in contact with the saw. The saw below the table should be encased. We are now trying-out a wooden guard, designed in one of our pattern shops, which we

expect to prove satisfactory. We also believe that all pulleys and belts in the pattern shop should be guarded, if there be any danger of timbers being caught in them.

It is also important that the knives of wood jointers be guarded. We have adopted an aluminum guard for this purpose, and it has been found to be satisfactory in every way. It is equipped with a strong spring to keep the guard constantly in position. We have equipped all of our planers with safety cylinders, which, instead of pulling the workman's hand into the knives, throws it out of the machine, and instead of losing his fingers or hand he sustains comparatively slight injuries. We have not had a report of a serious injury to pattern shop workmen from the use of the planers since the adoption of safety cylinders, and the use of the guard referred to.

Rubber matting in front of all pattern shop machines is recommended.

Machine Shops.

All gears and pulleys should be encased in metal guards. The standard requirements for gear guards is that the gears should be covered on the side as well as on the face, that the guards should cover the gears to such an extent that the danger of being caught between the end of the guard and the cog of the wheel will be eliminated, and an opening should be made, with sliding covers to enable oilers to do their work.

There is danger of having the limbs caught and sheared off between the table and the ribs of the planer bed. Workmen, contrary to rules, ride on the tables of these machines, and a guard placed over the bed eliminates this danger. When the beds are left open they are used frequently as a receptacle for tools, oil cans, etc.

All counter-weights should be encased by metal guards with door openings, so that the weights can be easily removed should they fall, without detaching the entire guard.

Power Plant.

The ends of piston rods, extending beyond the cylinder heads should be guarded, the purpose of the shield being to prevent the men getting so close to the cylinder that they will be struck by the rod.

All fly wheels should be guarded either with plate or wire net guards. All points on engine beds where oilers may have occasion to walk should be provided with screen or plate guards to a height of 5 ft. from the pillar blocks.

There will be an opportunity in almost all foundries to apply protection to such machines as charging cars, where it is found necessary to provide guards for the truck wheels. The gears on steam derricks should be covered, and men not allowed to ride on the body of the car nor on the coupling. Where a railroad track runs close to a building, railings should be placed at the corner of the buildings to prevent men suddenly stepping from the buildings on to the tracks. Wooden and S-shaped wedges have been used in the ends of sledge handles to prevent the sledges from flying off and causing an accident. Latches should be provided to keep the bails on sand boxes in position, and care exercised to see that they are in proper repair. Many serious accidents are caused by the absence of latches, or their being out of repair, and the bails falling on unsuspecting workmen. Pulley gongs should be used at scrap breakers to warn workmen in the vicinity of the falling of the "drop." The scattering of broken pieces of metal has been known to cause many accidents. Warning targets or flags should be attached to railroad tracks when men are working underneath cars to prevent engine from bumping into the cars and running over the workmen.

Cleanliness about the shop and yards cannot be too strongly urged, as there is no question as to its being a factor in causing men to be more cleanly about their work, and in preventing accidents due to untidy conditions. It is also true that shop windows should be cleaned at regular intervals, and illumination may be greatly improved by whitewashing the walls of a dark room at least once a year. This also saves much on the cost of artificial illumination. Mention may also be made of the risk of permitting unsuitable clothing to be worn. Leather leggings for the use of belt repairers will minimize the risk of accident, as there is considerable danger of these workmen having their trouser legs caught in moving machinery. One of the large railroad companies has recently forbidden the wearing of neckties by workmen while at work, as there is constant danger of these being caught in machinery and drawing their wearers into the machines. Gasoline should

not be carried in open cans. Safety gasoline cans, having a narrow spout opening with spring lid, will eliminate accidents caused by sparks from passing engines, or by other means, igniting the gas and burning the carrier.

The insistence on rules and regulations is emphasized by the persons having anything to do with the prevention of accidents, but I believe that these should be used sparingly, and be as brief as possible. They may give legal protection in damage suits, but they are practically worthless if no attempt is made to enforce them. I believe that a few effective rules insisted upon by educated foremen, in sympathy with the full protection of their workmen, will be far more effective than a long list of work rules which few will read and none will remember.

I believe that money and effort expended for the protection of workmen in foundries and other industries will be returned many fold in the form of a better and more suitable organization, and a large saving in the accident expense account.

AMERICAN FOUNDRYMEN'S ASSOCIATION.

RATIONAL CUPOLA MELTING PRACTICE.*

By Dr. Richard Moldenke, Watchung, N. J.

With all our advances in many directions in the metallurgy of cast iron, the foundryman has often asked himself why the cupola has not come in for some of this improvement. When he gets a persistent run of iron which has too little "life" to suit his requirements, when pin holes in important surfaces return him a lot of work, and when he cannot find the difficulty in iron or coke, he has only left the hope that he will gradually work out of the trouble. Eventually he does, and when comparing notes with his foundry friends they all come to the conclusion that "every cupola has habits of its own," and there the matter rests.

If there is one thing in manufacturing practice that is most unfortunate it is to get out of trouble without knowing how it happened. If the difficulty were overcome by the introduction of well-defined changes, one would know just how to proceed next time, and hence the necessity for studying the melting process in detail, in order to discover the principles underlying the melting of iron when exposed to the influences existing in the cupola furnace.

What follows below is based upon the results of practical experience. The first incentive to the study of cupola melting was had in the elaborate coke tests made at the St. Louis Exposition. Later, these were built upon by an elaborate investigation by the government, the results of which are a corroboration of every claim made in this paper. When the rules for cupola charging laid down herein are compared with the catalogues of cupola manufacturers, and with the published statements of a number of authors who give advice to foundrymen, it would seem that some one will have to make some revision. The writer will leave it to the foundryman to make the comparison indicated

* This paper was also presented before the Iron and Steel Division of the American Institute of Mining Engineers, Cleveland meeting, October 29-31, 1912.

and draw his own conclusions. If, when he gets into trouble, he will follow out what is advised at the end of this paper, he is certain to know more about his cupola than he did before. The writer will simply say that in a few hundred cases where he was called in professionally to cut down the discounts to a normal figure, in but rare instances did he have to change mixtures, metal or coke, but in all of them the methods of charging and melting were adjusted to the principles outlined in this paper, and success followed as a matter of course. The foundryman will notice that the subject is a very simple one, once point after point is reasoned out in a practical way, and that after all the application of scientific principles in the simplest way possible results in the best practice.

Experience with the cupola has shown that it is necessary to have the melting done at one place throughout the heat. This is the place of maximum temperature and is readily noticed on looking at the lining, by the heavy cutting action of the slag and iron oxide during the melting operation. The design and operation of the cupola must therefore conform themselves to the point above mentioned. Once this has been attained, the other considerations resolve themselves into construction details giving the least trouble for repairs, with smallest expense.

The cupola is practically a shell of steel lined with a refractory material of the proper kind, and provided with a set of tuyeres to allow air to be driven into the fuel and the charges to be melted. It should have the same diameter throughout, as there is no reduction of ore and consequent change in bulk of material to hold. The tuyeres should be of an almost continuous type, as it is important to keep the zone of maximum temperature above them (as indicated on the lining) a practically level one. The tuyeres are placed at a point such that, allowing for slagging off below them, there is sufficient room to hold the required quantity of molten iron without danger.

In cupola melting practice it is necessary to burn the fuel as completely as possible, in order to attain the maximum temperature available. That is to say, the carbon of the coke or anthracite—whichever happens to be used—must be converted to carbon dioxide, with as little subsequent change to carbon monoxide (by taking up extra carbon from the incandescent fuel) as may be possible. If this desirable condition is effected at the point where

the metal charge has been placed, melting under the most favorable conditions ensues. The molten iron is superheated properly and the chances of oxidation in melting are reduced to a minimum.

There follows from the above that in order to get the conversion of the fuel into the maximum of carbon dioxide, not only must the bed stop at the point where this is produced and no more fuel allowed over it, but the proportion of air blown into the cupola and the diameter of the cupola must stand in some relation. It is well, therefore, to look a little into the rationale of the process of combustion taking place in a cupola. Let us suppose that a given cupola has had the bed charged and well burned through, the first metal charge has been put on, and then the succeeding intermediate charge of coke which is intended only to replace that portion of the bed burned away in melting the first metal charge. The second metal charge is now put on, then again coke, then metal, and so on. It is desired to start up melting. The blast is put on, and this is what happens: As the air enters through the tuyeres and thence into the fuel, every molecule of oxygen that touches the incandescent fuel picks up enough carbon to make a molecule of carbon dioxide, and this travels along upward through the incandescent bed. Now some of the molecules of this carbon dioxide must naturally be changed to other molecules of carbon monoxide by their contact with more incandescent coke, but as there is a lot of free oxygen present, not to speak of the nitrogen molecules in great abundance, which serve to protect the finished CO_2 from becoming CO, it would take some time and space to travel through to change the bulk of the CO_2 to CO. As a matter of fact, the maximum CO_2 under ordinary conditions is reached at eighteen to twenty-four inches above the tuyeres, the bed being sufficiently thick to allow this. If more incandescent fuel is above this (as would be the case in producer gas practice) then the change from CO_2 to CO is rapid, and the poor melting results quickly noticeable.

While the above-described process is going on it will be seen that it is quite easy for some free oxygen to reach a considerable distance up into the charge before being used up in the combustion process. In fact, tests on this point by the United States Bureau of Mines have shown conclusively that there is really no place in the cupola absolutely free from uncombined oxygen.

It was further found that a lot of the air practically escaped unchanged along the lining, and hence the danger of charging all the heavy iron along the lining, where it is just in the right place to become oxidized as it gets into the melting zone.

A further interesting point proved by the government investigations just mentioned is that there is a central cone in the fuel bed of the cupola above the tuyeres in which there is a formation of CO only, showing that no combustion goes on at all there, which indicates that as the air is blown into the cupola it curves upward and some of it does not reach the center directly opposite the tuy eres. The smaller the amount of air going into the same diameter cupola the higher this cone will naturally be, and if it should extend beyond the original bed height (after melting for some time) by catching accumulations from the subsequent coke charges, there will be a diversion of the metal charges outward from the center as they descend, and the melting done in the cupola will be curtailed considerably from normal conditions, besides forcing the cupola to melt in a very uneven manner. On the other hand, the more air is blown into the same diameter cupola, the shorter this cone becomes, disappearing altogether when the air is forced straight through the bed. This is about the ideal condition, and any further forcing of the air by using larger quantities will increase the melting capacity of the cupola unduly, compel the raising of the coke bed, be apt to start channels in it which send all the air through a portion of the bed only and will consequently oxidize a lot of iron and be generally unsatisfactory all around.

The above somewhat involved explanation indicates why the amount of air blown into a cupola should bear a relation to the diameter. Practice is the best guide to this. For instance, take the ordinary cupola with 54 in. diameter inside the lining. It takes a little less than 30,000 cu. ft. of air to melt a ton of iron. Under the best conditions of practice this cupola has been found to give ten tons an hour. Hence we must provide 300,000 cu. ft. of air to go into that cupola per hour, and see that it really goes in. It is possible to get good results with less air, but then the melting rate drops, and this is bad foundry economy. On the other hand, it is possible to get eleven and even twelve tons an hour from the cupola, but this means blowing in the corresponding amount of air with consequent chances for bad working.

There is therefore a safe rate of melting for each diameter cupola, and this is given by the catalogue of all makers, as taken from experience. If a given cupola does not perform in accordance with this rate, and the amount of air blown in has been found to be the correct one—allowing 30,000 cu. ft. per ton to be melted—then the trouble must be looked for elsewhere. A discussion of this matter will follow.

Taking up next the question of cupola temperatures. As the blast goes through the fuel bed the gases become hotter and hotter up to the point of maximum CO_2, and this may be some 3900° F., theoretically. At this point, which is some eighteen to twenty-four inches above the tuyeres, as previously stated, the hot gases should find the charge of metal to melt. If there is fuel above this yet, by originally charging too much fuel, the conversion to CO takes place, with consequent reduction of the temperature. It will therefore be seen that from the actual entrance of the air into the bed, there is a rapid increase in temperature upward until the maximum is reached, and then a decrease again. Experience shows that the melting of iron is possible about a foot below this maximum temperature, and perhaps two feet above, if the bed were allowed to be so low or so high through improper charging. And this can be readily understood when it is remembered that the melting point of the white irons runs as low as 2000° F., with the gray irons several hundred degrees higher. The iron melts, but in the case of too low a bed it will be insufficiently overheated, besides having been exposed to free oxygen with all the trouble this brings about. In the case of too high a bed, the metal has not been oxidized, but is so cold that even dropping through a hotter portion of the bed will not give it the proper casting temperature.

To find the proper height of bed—and this height is not a function of the weight of the fuel, but the amount of travel the air has to perform through it until the maximum CO_2 has resulted and with it the maximum temperature—experience again has taught us how to go about this. It has been observed that when conditions in the cupola are just right for "blast to go on," which is to say when the bed is well burned through, and the cupola charged to near the door with the metal heating up nicely, it should take between eight and ten minutes from the commencement

of blowing until enough iron runs from the spout to necessitate closing up the tap hole. The melting iron dropping by the peep-holes in the wind-box will be observed in about five minutes after blast is on, but it takes a little longer to have enough metal come down to begin running out. If the metal under these conditions comes in less than eight minutes, the bed was too low, and should be increased by adding a little more fuel between metal charges to bring it up properly, and the next day the bed should be made higher in the first place. If it took longer than ten minutes, then the bed was too high and should be reduced correspondingly.

Looking at the actual condition of the bed in view of what has been said so far, we find that every portion of it below the tuyeres is simply so much filling intended to give storage space between the lumps of incandescent fuel for the molten metal. Above the tuyeres we find the chemical reactions of combustion going on which result in maximum temperature conditions at a given point above—and at which melting should be done. It will further appear that only the upper few inches of this bed will be of the maximum temperature, and below this the bed is cooler and contains the dreaded free oxygen. Hence the metal charge should be so proportioned that it is melted down completely by the time about four inches of the bed has been used up in doing this. The correctness of this statement can be observed at any time in looking into the interior of a cupola the morning after a melt. In a well-regulated shop the scoring of the lining is confined to a belt of about four to six inches. In a shop where the reverse conditions exist—though doubtless unknowingly, as it will be found in the best of our foundries—the affected belt of the cupola lining may be three feet in extent. The latter condition shows a shifting of the melting zone up and down accordingly as the bed has been allowed to burn away before the succeeding coke charges came down to replace it, or the bed had been allowed to go up by too much coke between charges.

The inferences that must be made from the above are first, that the smaller the metal charge and oftener repeated, the less the shifting of the melting zone up and down in the cupola. Second, that it is a serious mistake to adopt the almost universal rule in this country to make the first charge twice as heavy as

the succeeding ones. Where this is done, it is patent that double the amount of coke must have been burned away from the top of the bed, only half of this being replaced by the first intermediate coke charge, and from the second charge of metal the melting is done at a lower point in the cupola. It is difficult to instill this point into the minds of cupola men and even chemists. They see a big pile of coke go into the cupola for the bed, and of necessity hold that a big lot of iron should go on it, forgetting that only the very upper portion of the bed does the work whether the bed is big or little. European practice is more rational in this respect, for not only do they use small diameter cupolas with consequent effective blast penetration, but they also make very small charges and no big first charge. Like many other things, we over-improved the melting process when we got to doing the big things common here.

While the weight of the coke for the bed is not essential, it is very much so for the intermediate charges. That is to say, once the proper height of the bed has been found for a given coke, the replacement of what is burned away in melting each charge is a definite function of its composition and somewhat of its cellular structure. Every time the supply of coke is changed it is necessary to try out the melting time for "first iron." In fact, in well regulated shops this is done every day—unless the shop custom is to keep the breast closed during the "burning through" and "blast on," when it is sufficient to make the above described time trial once a week or so. It is also necessary that the fuel for the bed should be perfectly dry, though this is not essential for the upper charges, provided due allowance is made for the water in weighing up, as the carbon content is wanted in the right proportion.

It is therefore well to use another experience figure for the weight of the intermediate charges of fuel. This is one-tenth the weight of the metal charged above it which it is to melt. A good high fixed carbon coke can melt more than ten times its weight, or the ratio is, say, above eleven pounds metal to one of coke, while a high ash coke works the other way. Hence we have gotten to the point where in trying out the melting conditions required for a cupola, the first iron is wanted at say eight minutes, the first charge of metal as small as all the others, and the

coke charges between these metal charges one-tenth in weight. It now remains to fix the size of the metal charges.

Since about four inches of the coke bed only should be burned away in melting the metal charge above it before the next coke charge comes down, it stands to reason that the proper size of the metal charge should be that which takes these four inches of coke to burn away, or ten times the weight of four inches thickness of coke in the cupola. The best way to find this out is to lay a ring of cupola blocks or fire-brick on the cupola charging floor of the diameter of the cupola, and four inches in height. Fill this space with the coke in question and weigh it. Ten times the weight is the amount of metal to be charged. The ideal condition is really to take the proper proportions of pig, scrap and coke, mix them together as they are charged, and thus in the melting a lump of coke replaces one just being burned away, and there is no shifting of the melting zone at all. It is an expensive way, however, and one is apt not to get the proportions charged correctly.

Inasmuch as during the course of a melt the cupola becomes hotter, and the upper charges well heated, naturally less coke is required between the charges, and here the experience of the foundryman comes into play. The easiest method of determining this question is to observe the melting rate. That is to say, if a given cupola melts ten tons an hour for the first hour, and only nine the second, this has been because of excessive coke (other conditions being right), and a gradual and slight reduction of the intermediate coke charges is in order, until the melting rate is restored and even accelerated a little. Continued observation quickly overcomes this difficulty.

It might be stated here very emphatically that the current practice of giving a bonus in the foundry for saving coke is radically wrong. There is only one right proportion of coke to use. If more is used the melter should be replaced. If less the manager is at fault in allowing it. If the foregoing deductions have been followed closely, it will be realized how easily a cupola can be charged and run.

Oxidized iron is very difficult material to get good castings with. It seems that when the melting iron gets into portions of the cupola where free oxygen is present, it is affected thereby and

the result is a higher freezing point. The metal loses its "life" and cannot be held for any time safely. Moreover, it contains gases which come out at the moment of set, with the result that the castings show evidences of pin-holes, heavy shrinkages, and even cracks from loss of power to accommodate themselves to internal strains while the metal is setting. And still worse, the pin-holes in question oftentimes do not appear until the skin of the castings is removed by machining. This is because when the mold is poured the metal immediately in contact with the sand sets first, and in doing so passes its contained gases through it. Once this skin has formed, further gases attempting to get out are shut off, rise to the top, and will remain just under the skin. Metal of this kind always shows defects when the cope portion is planed off. The bottom of the casting as poured may be all right.

Since this condition is entirely due to the oxidation of the metal, it is important that in charging the cupola this be done very evenly and regularly. That is to say, not to charge the pigs around the lining and the scrap in the center. Not only will the bulk of the metal thus be exposed to the gases rich in free oxygen which pass up along the walls, but there will be practically sixteen pounds of metal or more to be melted by the pound of coke underneath along the outside of the charges, and say five pounds of metal only for the pound of coke underneath in the center. The result can only be trouble, especially where small castings are made, for the comparatively cold iron from the outer portion of the cupola while mixing with very hot interior portion may give a mixture hot enough to pour all right, but that sixteen to one metal has been damaged by oxidation and this leaves its effect on the mixture.

The subject could be extended still further by giving many and varied examples from actual experience, but enough has been said to indicate that the cupola is by no means the simple contrivance that it is supposed to be, and that there are refinements in practice which take into account peculiarities in fuel, metal and even the air used for combustion purposes.

If the subject may be summed up at all, the following points should be looked after:

See that the proper amount of air gets into the cupola for its capacity.

See that the bed coke is dry and well lighted up before charging.

See that the bed is of proper height to give "first iron" in eight to ten minutes.

See that all your metal charges are alike in weight.

See that the metal charges are no larger than requiring coke enough to just cover the metal below.

See that coke charges are so adjusted to the metal charges that the melting zone remains stationary throughout the heat and at the right point.

See that the blast volume (not pressure) never changes throughout the heat, as this immediately changes the position of the melting zone.

See that your charges are evenly distributed, pig iron over the entire bed first, then scrap also over the entire bed, then coke. If steel is used, put on before the pig. Never use thin scrap steel.

Use only one row of tuyeres and have them large enough. If a second row is available, open only a very few of them so as not to disturb the position of the melting zone, while giving extra air to burn the CO that may form too low.

Watch the melting rate and adjust intermediate coke charges accordingly.

Avoid charging very large pieces of metal, as these often deflect the gas currents and bring about uneven burning of the fuel.

Heavy cokes, with small cell space percentages, can stand large charges, anthracite coal being the extreme in this. Light cokes, with large cell space percentages, must have very small charges to get best results.

Where the above suggestions have been tried out, the result has invariably been snow-white molten iron from the spout of the cupola, perfect mixing of the iron charged and sound castings. It is to be understood that this covers the metallurgy of the cupola melting process only, and that the mechanical considerations looking toward extreme economy in operation as well as original design have not been touched upon.

MALLEABLE CAST IRON AND THE OPEN HEARTH FURNACE.

By G. A. Blume, Stockholm, Sweden.

In times gone by, before the light of scientific investigation dispelled the secrets of the wise old men at the air furnaces, and when the "test plug" and the annealing "heat-color" were inheritances highly treasured and carefully guarded, little was known by the foundry fraternity on the subject of making malleable castings. These times are not yet so very far off, and in spite of our associations of foundrymen, foundry literature and information readily obtainable, there are still some deluded mortals existing who live in the happy simplicity of mind believing that but few have acquired the "art" of making malleable castings.

The fullest development of the art has been brought about in America, and much of this has been the result of the elimination of cut-and-dried methods, and the establishment of the process upon a scientific basis making for certainty in results. From crucible melting to cupola melting, with the air furnace in constant use, with the old annealing furnaces direct fired and doors to be bricked up anew every time they were charged, we have come to gas firing, oil, coal-dust ovens, to be closed in a few minutes and holding perhaps fifty tons of castings. The pyrometer is replacing the eye-sight and molding machines, conveyors, and finally the laboratory are lifting the veil of secrecy. The change has indeed been astonishing and rapid when it came.

And we are not finished yet. New methods must be found to make still more certain the results wanted, and new lines of installations to cheapen production in this interesting branch of the iron industry.

Cupolas and even crucibles for malleable work are still more common in Europe than air furnaces. So many workmen, foremen and engineers come to America and return home again with

the knowledge gained, that one would think European practice would soon be modernized. In reality, however, it has been found that in most cases this is not possible, and for reasons that have no bearing on this paper.

The author for one has tried to run a malleable-iron foundry in Europe with the application of American methods, but it was very soon apparent that great modifications were required to accommodate these methods to the "surroundings."

With a smaller market, with another class of labor, with social labor questions to be reckoned with, with different kinds of raw material, with bituminous coal at $5.50 a ton, etc., it soon was evident that it was not be thought of to apply the systems which are common in America unchanged.

Among others, the question of melting-furnaces soon became a problem which could not be solved so easily. The furnace at first built was of the air furnace type, that is, with a comparatively straight top, a narrow opening into the stack and blast both below the grate and through four nozzles over the bridge; the melting capacity was about eight tons per heat.

Very soon, however, complications arose, caused by the town authorities, who viewed with awe the beacon of flame which issued from the top of the short smokestack and which frightened the good people living about. Furthermore, good coal was hard to obtain and was very expensive. The same with good men, capable and willing to handle the coal shovel and to rabble the iron bath. Last but not least, the loss of heat which poured through the stack, a benefit for the birds alone, was an eyesore not to be long endured.

However, it was not an easy matter to decide in what direction alterations ought to be made, especially as it was plain that the shape of the furnace, size of flues, pressure of blast, etc., were matters which could not to any great extent be safely tampered with nor improved to any appreciable degree.

Experiments were then made with a new air furnace using preheated blast, which was forced through flues running under the neck of the furnace; but, partly through errors in this arrangement and partly for other reasons, the scheme was soon abandoned, when it was shown that the advantage gained, if any, was at best very small.

A suggestion to make the air furnace recuperative through the building of heating chambers underneath the floor level and below the furnace proper was finally turned down on account of the cost it would entail in face of a dubious and certainly not complete success; *i. e.*, sufficient saving in fuel and labor, etc.

Another scheme, to build a gas generator in the firing pit of the air furnace together with arrangements for the preheating of the blast by running it through pipes in the base of the smoke-stack would have been carried out had it not been that a further development of this principle evidently pointed more directly to the most successful and economical furnace in the metal industry of to-day, namely, the Siemens-Martin, or, as it is called in America, the *open hearth furnace*.

That the use of open hearth furnaces in the malleable cast iron industry is not a novelty, is a fact well known to the author, and to judge from the statements set forth in Dr. Moldenke's book on Malleable Cast Iron, its application for this work has been successful, at least, within his own experience.

As it was evident, however, that the introduction of this kind of melting equipment would entail a very considerable outlay of money as well as it would if carried out to the full extent of its possibilities, certainly cause an almost complete revolution of the whole system previously employed. The author made arrangements to conduct a series of trial meltings in an acid open hearth furnace at one of the best known larger steel works in Scandinavia. These experiments proved very satisfactorily the value of the open hearth furnace, and after that no doubt remained any longer as to the course to pursue regarding melting furnaces for malleable iron foundries.

In this connection it will be of interest to know that the author had occasion to discuss his plans regarding the introduction of open hearth furnaces in the malleable cast iron field with two gentlemen from America, both holding leading positions in a very large malleable interest in that country, and that the verdict of these parties was altogether discouraging. They had themselves in their foundries expended more than $100,000 experimenting with open hearth furnaces, but had come back to the air furnaces, and to their knowledge other foundries in America had also had the same experience.

The experience of the author with the open hearth furnaces for malleable purposes has, however, now been sufficiently wide to entitle him to lay before the American Foundrymen's Association a narrative of how it was obtained, and it would be a great pleasure to him if some impulse could thereby be given to those interested in the question to carry the suggestions here to be made to further proofs.

It was in December, 1910, that the first application of the open hearth according to the author's suggestions was made and a second furnace was built during 1911 and started in the beginning of this year.

As natural gas is unknown in Scandinavia and oil is only to be had through import from Russia or America, it was necessary to use producer gas as fuel. The result, generally speaking, which could be expected by carrying out the plan of substituting gas firing for coal fires in not only the melting furnace, but also in the annealing and core ovens, was saving in fuel, no waste heat, saving in labor through the concentration of the heat generation, and the possibility of more minute control of the manufacturing processes, etc.

As carried out the second time, as above mentioned, the system has resulted in a complete centralization of the heat generation to one gas producing plant from which the gas is conducted to the open hearth furnace as well as to the annealing furnaces and core ovens, while it is also to be used for other purposes later on.

It has been previously observed that one of the difficulties met with in attempts to transplant American methods to Europe, is the limited market and this is of course a matter especially noticeable in the smaller countries.

As the plant referred to above was built in Finland, a small country with hardly more than three millions of inhabitants and with very few industrial enterprises, it should be plain that the conditions there are not comparable with those in America, and that also the benefits derived from the introduction of modern labor-saving devices must be limited.

In Figs. 1 and 2 are shown the exterior as well as the interior views of the foundry referred to. The furnace equipment consists of one acid open hearth furnace of a normal melting capacity of

two and a half to three tons per heat, two annealing furnaces and one drying oven, as well as a cupola and two brass melting furnaces.

The gas plant consists of two cylindrical gas producers with the inside diameter of about five feet. Of these, however, more than one is never used at a time, the other being kept in reserve, and in case the building of more furnaces should be deemed advisable. The gas from one producer is sufficient for the whole furnace equipment (cupola and brass furnaces excepted), even if all are running at the same time, although as a rule the annealing furnaces are run alternately.

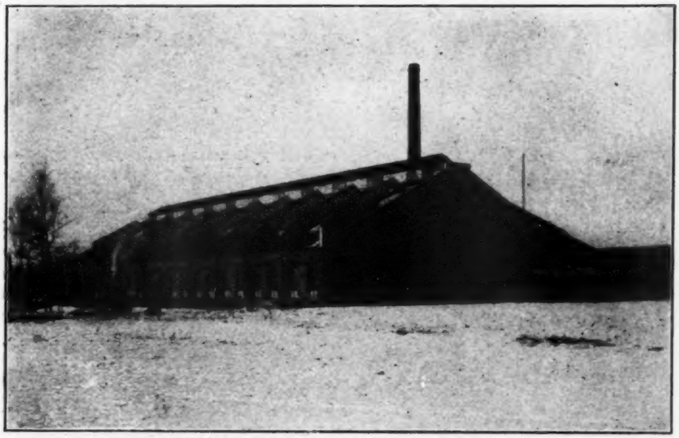


FIG. 1.—EXTERIOR VIEW OF FOUNDRY.

That the open hearth furnace must be built with an acid lining ought to be plain, as there never can be any question of any refining process similar to that taking place in the making of steel in basic furnaces.

When constructing the open hearth furnaces above referred to, the author, by reason of his previous experience wished to embody certain principles with a view of making them more suitable for the purpose intended, *i. e.*, the melting of pig iron and white scrap only and this without endangering the iron through undue oxidation. However, the main principles of the

FIG. 2.—INTERIOR VIEW OF FOUNDRY.

steel making acid furnaces were followed, at least to the extent that should it be desired even steel could be made.

The principal points kept in mind have been the size of the regenerator chambers for air and gas, the method of building the checker work in these, the sizes and above all the direction of the air and gas flues as well as the manner and place in the melting chamber, where gas and air mix and the combustion takes place.

Ease of access to all parts of the furnace and the possibility of cleaning the system of flues, especially those for the gas, which naturally is comparatively extensive, have all been matters considered very carefully.

It is also interesting to note that the furnace is built so low that the tapping spout is not more than three feet above the foundry floor, and the charging platform only about two feet. Because the furnace is so low tapping can be done in exactly the same manner as with the common air furnace, *i. e.*, in small hand ladles, while on the other hand nothing prevents placing a large crane ladle sunk into the floor pit, under the spout, if it should be so desired.

Fig. 3 shows the platform of the open hearth furnace, illustrating the door hoisting arrangement.

The regenerator chambers are placed altogether under ground and directly under the furnace proper. Although this necessitated the building of an expensive 12 ft. deep concrete box with intermediate layers of asphalt to keep out the water from the surrounding water-soaked ground, and to place the whole furnace system in that box, this, in the author's opinion, was better than to place the regenerator chambers higher up and at the side, because he has found that the more the chambers are built to take the form of a chimney, *i. e.*, the higher they are compared to the area, the better the result will be and the more heat they will absorb and return.

Regarding the result of the application of this open hearth system, it can be said regarding the furnace started in December, 1910, that it has been in steady work ever since completion and that it worked well from the very start, although some minor changes, principally in the flues and in the mechanical parts such as reversing valves, gas main valve, and others, have been made later.

With this furnace it has been the custom to take off only one heat of two and a half to three tons a day and to shut the furnace down from afternoon until next morning as well as over Sundays, and this without in any way damaging the brickwork which has stood up beautifully and has needed repair only once a year. This means, however, only in the wall on the tapping-side, and around the doors and ports.

The latest built furnace, started in the beginning of 1912, has been melting from two to three heats a day and the trials

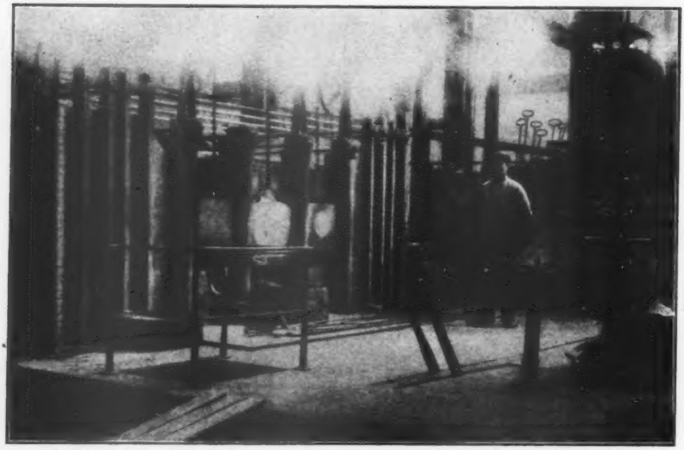


FIG. 3.—PLATFORM OF OPEN HEARTH FURNACE SHOWING DOOR HOISTING ARRANGEMENT.

made have been very exhaustive. Both steel, gray iron, and white iron (for malleable purposes) heats have been taken off right after each other within the twenty-four hours without any trouble. The quality of the product has in each case been very good and the furnace has shown a remarkable adaptability for different kinds of service.

Regarding the time required for the melting of a charge, the author wishes to say that a normal heat of two and a half to three tons of 2,200 lbs. of white iron requires, including the charging, about two and a half hours, although even three hours

have been necessary if unsuitable irons were used, if the charging was not done properly or the gas was poor, as was the case last winter, when coal was not to be had at any price by reason of the coal strike in England and the producer had to be fired with wood and refuse from sawmills so damp that it would hardly float in water.

The iron has been very hot and the control of the flame so perfect that the oxidation has been kept very small; in fact, cases have been noted where the reduction in silicon has been next to nothing. On the other hand, when occasion has arisen, as in trying new mixtures where the silicon content has been held rather high in the charge, and furthermore while making steel, the oxidation has been carried as far as the circumstances have required it.

The time required for taking down a heat of about three tons of gray iron is about two hours, while a little smaller heats have been charged and melted in about one and a half hours.

Although the normal capacity of the furnace is two and a half to three tons, charges as large as four and three quarter tons have been successfully melted.

In considering the time required for the melting and the raising to pouring heat of a given charge, it should be borne in mind that the time needed for a ten ton charge in a ten ton furnace is practically the same as for a three ton heat in a three ton furnace, so that it is not right to compare the melting time of unequal charges in different sized furnaces.

The author had ample opportunity to demonstrate this fact during his first above-mentioned experiments with the open hearth furnaces for malleable purposes.

The furnace then used had a capacity of eight to ten tons, and while a full charge required three hours, a smaller heat of three and three quarter tons could be charged, melted and tapped in a crane ladle in one and a half hours.

A question of very great importance in considering the melting of iron is the fuel consumption, remembering that the open hearth furnace requires continuous service. This furnace is lined with silica brick and for that reason must be kept heated at all times. To obtain a high heat in the hearth the checker work must be kept hot. Therefore, whether used or not used

during the whole of the twenty-four hours, fuel keeps on being consumed, although of course at a slower rate when the furnace is not melting.

The normal fuel consumption with coal in Swedish open hearth steel practice is 25 to 26 per cent of the weight of steel produced, while running steadily with three heats in twenty-four hours. The author's experience during the last six months with the open hearth furnace in malleable practice has been that the fuel consumption for the entire process of melting, annealing and core baking has amounted to one pound of coal for every pound of finished malleable casting; but it should be mentioned that the coal used was a very poor quality of German coal with a large percentage of slack.

It should furthermore be borne in mind that the furnace has been used during the night only exceptionally and that therefore large quantities of fuel have been required to raise the temperature of the checker brick in the regenerators and of the furnace proper to the necessary heat before charging in the morning.

There seems to be no doubt of the possibility of reducing the fuel consumption for melting white iron to a maximum of about 18 per cent if the furnace is worked more steady, *i. e.*, taking off four heats during the day and to still less if continuous melting can be carried on.

After each tapping the breast is broken up, the remaining slag drawn out and the bottom patched up, if needed, with some quartz; the breast is again filled in with old molding sand, and a short sand plug rammed in, whereupon the furnace is again ready for the next heat. The time required for this work took from twenty to thirty minutes.

Since the author had now proved to the satisfaction not only of himself but also of those whose money has paid for the installations, the practicability of the open hearth furnace, it has naturally occurred to him to ask why it is that several similar attempts in America have not turned out equally well. It has been his good fortune to see and examine an open hearth installation in a new malleable iron foundry in Germany which, like those above referred to, did not at first give satisfaction, although a few alterations soon turned it into a success, and this gave some good

pointers on the question of how that class of furnaces ought to be built.

As all malleable men know, the quicker the melting is done in the furnace, the better the iron, and similarly the more the composition of the metal remains unchanged, the better the result. The author knows of at least one foundry in America where the melting is done along other principles, but this seems to be an exception to the general practice.

A slow and irregular melting in a furnace which is working poorly will do more to ruin the iron than any other part of the process, and the author for one is a firm believer in the theory that the keynote of successfully making malleable cast iron lies in proper melting. A quickly and correctly melted iron of the right composition will suffer little damage in the annealing furnace even if the heat is irregular, but then again even a slight tendency to undue oxidation of the bath in the melting furnace will give a poor product, however well and carefully the rest of the process is carried out. To melt right, two things are needed: a properly constructed furnace and a skillful melter. Doubtless it is the lack of one or of both of these prime conditions which has been responsible for the failures.

It must be remembered that in the malleable iron foundry an open hearth furnace is purely a melting machine and it should be constructed with that end in view; furthermore, it should be handled as such. Many little things relating to the proper running of the furnace must be carefully considered. The manner in which the furnace is charged, *i. e.*, how and in what order the iron is placed in the furnace, the way in which the gas and air supply is regulated, how the damper is handled, the regulation of the pressure behind the gas in the producer. The experience of judging the bath from its general appearance, the testing of the iron and its fluidity, all are circumstances necessary to consider. Each and all differ from the air furnace, as well as from open hearth steel practice.

But if the furnace construction is not suitable and therefore the furnace is not working well for its purpose, and if on top of this the right man to run the furnace as it should be run is not "behind the gun," then no doubt the result will be poor and as a consequence the system condemned.

A comparison between the use of open hearth furnaces for melting and the older methods, principally air furnaces, shows clearly the very great advantage in favor of the former system and these are largely increased if the use of gas as fuel is carried further to all the other classes of furnaces and ovens needed in the foundry, so that one central heat-generating plant can supply all heat necessary for the whole equipment of furnaces. To judge the question fairly, the advantages as well as the drawbacks, such as the author sees them, will be taken up below and it is here where criticism is especially invited.

The open hearth furnace melts iron for less fuel expense than the air furnace; the iron can be overheated to a higher degree and therefore distributed in larger quantities to the different molding floors with the advantage of reduced labor for the molders while pouring as well as a quicker emptying of the furnace, which gives a more uniform homogeneous metal; the melting is done quicker and the control of the flame is far more exact, so that the changes in the chemical composition of the bath can be reduced to a minimum and all danger of undue oxidation avoided.

As a consequence of this the shrinkage of the iron will be less, the iron stronger and the required annealing temperature lower. Through the lessened oxidation of the bath the slag quantity will be very small and the melting loss in weight of iron reduced. The iron will in the open hearth absorb even less sulphur from the gas than is the case in the air furnace, although this is a matter without great importance according to the author's opinion about sulphur in malleable iron as expressed later.

The open hearth furnace, when skillfully managed, is always dependable, as regular in its working as a clock, the time required for melting a given charge is regularly the same, the quality of the iron tapped is also perfectly uniform, and this because the possibility of careful regulation is greater than in the air furnace.

The unskilled labor in connection with the working of the furnace can be reduced to a very easy job, as mechanical appliances can be used for charging and operating the producers and no coal shoveling and very little slag handling is required. Even the charging of the furnace is very quickly done direct from the working platform and can be made still easier and quicker by means of charging machines.

The open hearth furnace is cleaner than the air furnace, as no smoke is seen in the foundry, no dirt or ashes need be taken care of, the slag skimmings off the bath are very little and the furnace performs its work absolutely noiseless.

In connection with the reduced fuel consumption stands the avoidance of loss through waste heat. The combustion is very complete in the furnace and the smoke-stack temperature very low. Instead of the pillar of black smoke and thick flame which rises from the air furnace chimney, the smoke-stack from the open hearth plant emits only a light smoke and this practically only in the moments following the reversal of the system from one set of regenerators to the other.

The open hearth furnace requires very much less space on the floor than the air furnace of the same capacity, and by setting the furnace low the tapping can be done, if desired, in small hand ladles in the same manner as with air furnaces.

Furthermore, the frequently recurring repairs and broken-down bungs in an air furnace are reduced to a shut-down about once a year and can then be done in about ten days. The cost of repairs both in labor and material is thus reduced to a minimum.

In the air furnace the sand bottom must be relaid at least once every week and patched between times; there is no necessity for the relaying of an open hearth bottom more than in conjunction with the yearly repairing, while a slight patching up once in a while is all that is required.

One of the greatest advantages of the open hearth system is the possibility of obtaining a greater output with a smaller furnace as compared to air furnaces, because it is very easy to take off four heats in twelve hours, while three must be a maximum in air furnace practice if no overtime is resorted to. If, again, work in shifts is arranged so that the furnace can run steady during the whole twenty-four hours, then the output can be vastly increased, as shown later on below.

If gas firing is used even for other kinds of furnaces, large savings will be made in labor as well as in fuel. This has been clearly shown in the author's experience with such systems and in that way no heat will at any time be wasted, as there is always some one of the furnaces in operation on the same gas main.

We have finally to record the great adaptability of the open

hearth furnace to the melting of different kinds of material, as it can be used to equal advantage for not only white iron, but also for gray iron and for steel.

This is perhaps of slight importance in a foundry in which nothing but malleable castings are being made, but in the author's experience this general usefulness of the open hearth furnace has been a most valuable asset to the plant, when the demand for malleable iron castings at times was limited, but not to such an extent that there could be any question of shutting down. Then the use of the open hearth for melting gray iron and for making steel proved itself an extremely valuable proposition.

To an appreciable degree the advantage of adopting open hearth furnaces in the malleable iron foundries would be greater in those parts of America where natural gas or crude oil can be had at low cost. In foundries so placed the installations would be very much simplified and at the same time the operation of the furnaces cheaper both for labor and fuel. Furthermore, the coal account could altogether be dropped out of the calculations, while again the iron should be without any chance of absorbing sulphur in the furnace. If such possibilities were to be figured with on the other side of the "pond," then doubtless the adoption of open hearth furnaces or furnaces embodying the same principles would be still more general there than is now the case.

On the other side of the ledger come the possible drawbacks which must be considered when comparing the two above mentioned melting systems.

Doubtless there are those among the malleable iron men who would shake their heads and simply claim that the open hearth furnaces are not suitable in malleable foundries, and they would perchance back this assertion with their own practical experience.

To this the author will say, as before stated, that, rightly constructed and properly run, there is no better melting furnace for malleable iron foundries than the open hearth furnace and this for the reasons set forth above.

This opinion is backed by the records from those plants where, as stated, the tests have been exhaustive and where the furnaces have been in daily use quite long enough to have left the experimental stages far behind; and furthermore, there have been, and doubtless are at present, several foundries in America who are

using the open hearth successfully. Behind this latter assumption stand the statements of a distinguished man in the foundry field in America to-day, the secretary of this association. And then finally the author will put this question: Why, if not for any of the reasons given below, should the open hearth furnace not be suitable in malleable foundries?

But there are, however, some circumstances in connection with the issue which should not be passed lightly, and these are: the higher first cost of building, the possible difficulty of finding competent melters and the desirability that the furnace should be allowed to run continuously.

These three, let us so far call them disadvantages, should, however, be looked into more carefully.

So far as the higher cost of construction is concerned it must be remembered that many circumstances have to be weighed in judging this matter, because the local conditions have their influence as well as the kind of fuel to be used, and the relative cost of silica brick as compared with fire brick, etc.

But one must bear in mind at the same time that the same gas plant can furnish fuel also for annealing furnaces and for core ovens; that the capacity of an open hearth furnace can be made very much less than that of an air furnace for the same daily output, and also that the same chimney can be built to take care of *all* furnaces if these are placed locally within reach of each other. The difference in cost of construction will, when everything is taken into consideration, not be greater than that the reduced cost of repairs, let alone other advantages, will pay the interest on the bigger outlay of money in first cost.

It will doubtless seem absurd to many to even suggest such a thing as difficulty in finding competent open hearth furnace men in a country like America; but, on the other hand, it is a matter of pride for the author to recall the fact that the Swedes, even if they are behind in many things in industry, still in the art of steel making have as yet held their superiority and their furnace builders and furnace men still hold a leading position for skill and experience.

We should next look into the third of the "disadvantages" named, the desirability of running the furnace continuously.

That this is desirable if the utmost of profit is to be gained,

has been previously declared, but this does not exclude the fact that an installation will be profitable even if no heats are taken off during the night. Especially will this be the case if the annealing furnaces take gas from the same producer plant, when a small portion of the gas can be used in the melting furnace to prevent the heat in the regenerators from dropping too low. In that way the cost of keeping the furnace under fire at night will be very small and hardly to be reckoned with.

But then again, let us see if not the advantages of a continuous running foundry are also from other viewpoints so great that it should be a goal towards which all malleable iron foundries should work with all their might.

For a given output, the foundry proper can be built very much smaller and the melting furnaces need not be by far so large as is the case with a nine or ten hour a day place. From a three ton open hearth furnace there can be taken during twenty-four hours seven heats without difficulty and without forcing the equipment; this equals twenty-one tons of metal a day, or during a year of 290 working days (figuring away the time for repairs), in round numbers, 6,000 tons, making, let me say, 3,000 tons of finished castings, or equal to a ten ton a day plant.

The difference in cost between a three ton open hearth furnace and an eight to ten ton air furnace is, taking everything into consideration, not very great and certainly not so great that it should be a serious hindrance to taking the forward step.

The continuous running foundry will run with less overhead charges per pound of castings than a ten hour a day plant, the cost of production will be less and the returns on the capital invested should be greater. A continuous running foundry will reach a higher efficiency and it will stand a very much lesser chance of losses in bad times, as it will, if cut to half of its output, be very little worse off than the foundries which are built for day work only, when these are running full.

The author some years ago read an interesting article by Dr. Moldenke concerning the future of the foundry industry, in which he touches upon and sets forth his belief in the benefits of continuous work. This year an international committee working upon the same subject met, first in London and later in Switzerland, so that it seems as if the circumstances were point-

ing towards the twenty-four-hour working day in three eight-hour shifts. Then, to be sure, the open hearth furnace will have its day in the malleable iron foundries, if not sooner.

The author will next give some figures on the cost of building of open hearth furnaces, as well as of their yearly repair.

The cost of the latest built three ton furnace, above referred to, has amounted in round figures to $7,000. This includes two gas producers and all flues for gas, air and smoke, one blower with 25 H.P. electric motor, charging platform and accessories for the producers, the large concrete foundation box above mentioned, and all foundations, together with a 100 ft. stack of radial brick construction, which gives more than enough draft for two annealing furnaces, the open hearth, one core oven and two brass furnaces.

To give a clearer idea of the comparative cost, it should also be said here that good fire-brick 9x4½x2¼ in. cost $28 a thousand, 12x6x3 in. $36 per thousand, 9 in. silica bricks $45 and 12 in. silica bricks $60 per thousand. Crushed quartz costs $7.50 per ton of 2,200 lbs. and good so-called Dutch white clay $6.50 per ton. A mason gets $1.50 a day, but does no more than one-quarter of the work that a good American mason will do. An unskilled laborer gets 90 cents a day, but in comparison with the American he is worth less than 50 cents. The structural steel and plate work entering into the construction was figured at 5½ cents a pound and the cast iron at 2¾ cents.

The amount of crushed quartz sufficient for one year's run can be figured at ten tons and the cost of labor and material for the big repair once a year, together with fuel for reheating, can safely be put at a maximum of $400. Of course if steel is made the question of repair cost will take a different aspect, but that item should not in any case run over $600 to $800 per annum.

For a true comparison between the system of melting iron for malleable purposes in open hearth and in air furnaces or cupolas, it is not enough to compare the cost of the melting operations with everything belonging thereto, such as interest, depreciation, repairs, fuel consumption, cost of labor, in the same time as other pros and cons regarding the working of the furnaces are taken into consideration. Another very important question must also be carefully considered, namely, the quality of the metal and how it turns out in the annealing operation.

Even looked at from these sides, the open hearth compares very favorably with all other kinds of melting systems in use.

As far as the cupola metal is concerned, little need to be said in this respect, as in America the use of cupola melting in malleable practice is limited to certain classes of work. This much ought, however, to be told, that the author has very emphatically confirmed the fact that cupola metal requires higher heat and longer anneal than does metal melted in open furnaces of all kinds. The identical mixture required, when melted in the cupola, fully 1825° F. to 1900° F. during 96 hours, while if melted in the open hearth, 1650° F. during 12 hours and 1450° F. during 60 hours was enough.

Furthermore, to get a good black heart fracture from the cupola metal was practically impossible, while no difficulties were met with when the open hearth metal was treated.

The malleable men who notice the statement above made that 1450 to 1650° F. were needed for the proper annealing of the latter iron, will probably feel inclined to say that no such heat is needed in American practice to get the very best black heart fracture, and such a criticism would be quite justified. But the reason for using that comparatively high temperature shall be explained shortly in conjunction with reference to some notes on sulphur which the author desires to mention in this connection.

However, not only against the cupola melted white iron but also compared to air furnace metal, the author has proved the superiority of the open hearth iron to his satisfaction.

A certain hematite pig iron, made in Cumberland, England, has been used by the author for several years in air furnace practice with good results, it being especially easy to anneal compared with previously used Swedish brands, but it was necessary at all times to mix that iron with others in order to raise the silicon and phosphorus because the oxidation of the former in the air furnace as a rule brought it down too low in the bath, while the fluidity suffered from lack of phosphorus.

The analysis of the pig iron in question is as follows: Si., 0.90—1.00; S., 0.025; P., 0.020; Mn., 0.40—0.60.

The proper annealing heat for this iron, melted in air furnace, was 1425° F. during 72 hours full heat. When later using this very same iron in an open hearth it soon showed its superiority

to other brands previously tried, and although it was used together with the white scrap from previous heats, without adding a pound of any other kind of pig, the result was and is continuously a fine, fluid and hot metal, which shows a very slight reduction of the silicon during the melting and which is sufficiently hot to run well even with the low phosphorus given above. Even in the anneal this iron showed up better than when melted in the air furnace and it gave and still gives a fine strong black heart casting after annealing at 1325 to 1375° F. during 65 to 70 hours.

A few words have been said above about an annealing temperature of 1450 to 1650 ° F. and this brings us over to the chapter of the suitability of various kinds of pig irons for malleable purposes as well as to the interesting question of whether sulphur is a detriment in malleable cast iron or not. It is true that these issues do not come under the heading given to this paper, but they are not so far away that their mention in this connection can come altogether amiss.

At the plant where the new foundry and the open hearth installation above referred to was built, malleable cast iron had for several years been made according to the Réaumur method by melting in a cupola and annealing at 1825 to 1900° F. during a period of fully 96 to 120 hours of full heat. The fracture of the annealed castings was steely.

The pig iron used was of English make and of two kinds, the one gray and the other white. The former analyzed 1.97 silicon, the latter 0.45, while the sulphur ran from 0.18 to 0.25.

The mixture was made up of both these kinds of pig iron, a large percentage of wrought iron and steel scrap and the foundry's own hard scrap.

It is not the intention here to touch further upon the methods pursued, but only to state that when the new melting and annealing installation in a newly built foundry was ready a stock of the above mentioned high sulphur pig irons remained unused, and because no other more suitable irons were to be had in the country, and by reason of the time of the year and the great distance from open seaport none could be gotten except at a very heavy extra cost, attempts were made to use these high sulphur irons, and the charges were made up of these together with the hard scrap in suitable proportions.

The iron did not turn out altogether satisfactory in the furnace and was slow in getting up to pouring heat, but could be used very well. The annealing temperature at first tried was 1650° F. during 80 hours and when this showed over-anneal, it was kept at 1650° F. only about twelve hours and then gradually dropped to 1450° F., where it remained for 60 hours and gave a good and strong casting with black heart but of a decidedly grayish tint. The analysis of the castings gave: Si. 0.80, S. 0.22, Mn. 0.20 and P. 0.10.

In the same annealing ovens in which these castings were annealed some castings from previous cupola melts were also taken in, but after having been in the furnace twice they still remained glass-hard.

The analysis showed Si. 0.45 to 0.60, and S. 0.26.

Since two different trial lots of English hematite malleable pig irons, both analyzing Si. 1.00, S. 0.03, Mn. 0.40 and P. 0.04, had been obtained, mixtures were made up of them and some of the old high sulphur pig, in order to work up the stock as soon as possible. While the S. in that way was brought down to 0.10 to 0.12 or thereabout, the annealing temperature could be dropped to a maximum of 1450° F. during 72 to 78 hours, and the fracture was still black heart, but a trifle grayish, while the strength and malleability were well up to standard.

Castings from mixtures containing no high sulphur pig, but only either of the above mentioned hematite pig irons and white scrap and annealed together with the castings containing 0.10 per cent sulphur, showed decided over anneal and gave better result with temperatures around 1375 to 1425° F. during 72 hours.

The author's experience as related above seems to show that sulphur is not dangerous in malleable castings, not even if they are to be black heart, but that the required annealing temperature must be increased with higher sulphur. The commonly recognized influence of sulphur in cast iron is that it increases the hardness and makes the fracture dense, wherefore it is a desirable element in such castings as for instance cylinders. It seems therefore but fair to surmise that the influence of sulphur in white iron is similar and that the higher annealing temperature required is caused by the density of the structure, *i. e.*, the closeness of the molecules in the iron to each other.

In a similar way it seems possible to explain the fact that certain brands of iron, although the chemical analysis will lie within the limits commonly recognized for good malleable pig iron, need higher annealing temperatures than others. For instance, this is the case with the Swedish charcoal irons, in which the fracture as a rule is very dense and the strength high.

Similar to the influence of sulphur seems to be that of manganese and the effect on the hardness of cast iron is the same. It is also certain that the annealing of white iron with too high manganese is extremely difficult if not altogether impossible.

In the English or American literature on malleable iron the author has not been able to find any fully acceptable explanation of the differences between the black heart malleable and the Réaumur malleable, *i. e.*, the malleable with steely fracture. As far as he has followed the few opinions given it seems that the American experts put the matter to one side simply with the explanation that in the manufacture of black heart malleable the annealing—or decarbonizing process—is stopped as soon as the surface of the casting is decarbonized and the carbon in the interior converted into "temper carbon," the amorphous form of carbon so well known in American practice. In the Réaumur or "German" process, on the other hand, it is said the decarbonizing process is carried further until all the temper carbon is gone and what remains of carbon is in the combined form, while the fracture of the casting is steely and of an even color right through. Well, that sounds all right, and is doubtless true, but in the author's opinion it is only half of the truth, as there is certainly a little more behind the difference than just the annealing temperature and time for annealing.

A further discussion on these lines would however carry this paper too far away from the open hearth furnace and will not be continued, although the question is a very interesting one and if fully gone into would do a great deal towards a clearer understanding of the annealing process.

There have been mentioned above a few words about the more or less pronounced suitability for malleable purposes of different brands of pig iron, the chemical analysis not being considered.

While experimenting with different brands of malleable pig iron in open hearth and air furnace practice during the last seven years

or more, the author has had ample opportunity to test the truth of that assertion.

For instance, the two English-made malleable pig iron brands from hematite ore, previously referred to, showed pretty good results; the iron melted quickly and "took heat" reasonably soon after the bath had been skimmed once. The analysis of these irons is: Si. 1, S. 0.03, Mn. 0.40, P. 0.04.

When these brands, however, were compared with the Cumberland hematite pig iron which has been referred to above in other connections, the difference in favor of the latter was very marked. The analysis of this latter brand is: Si. 0.930, S. 0.025, Mn. 0.450, P. 0.020, or, as seen, so very near the same as the others that it cannot be the chemical composition which is responsible for the difference, but probably rather the ore from which the iron is made and the manner in which it is made. The expression is sometimes used that one pig iron has more "body" than another and for the trained eye the fracture of the pigs will disclose a great deal of their qualifications for the melting systems followed.

Before finishing, a few more words will be added regarding what previously has been called the adaptability of the open hearth furnace. It had long been the author's desire to in some way use the old burnt annealing pots in the foundry work instead of burying them in the ground or, if luck was good, sell them to a dealer. Previous attempts to melt in a cupola the very much burnt iron together with common soft foundry pig iron have not turned out quite well, but in the open hearth this is done with good results, and an iron good enough for common purposes is obtained. In this case the pig iron, as high as possible in silicon, is first melted and then the pot scrap added in such proportions as the bath will stand.

A great deal more could be said before the subject of this paper is exhausted, but what has been touched upon here might serve as a basis for discussion of the very important question of the best melting systems for malleable cast iron practice.

DISCUSSION ON MR. S. R. ROBINSON'S PAPER ON "SOME SALIENT POINTS OF THE MODERN STEEL FOUNDRY."

Mr. Lansdowne.—I would like to ask a question. Why are iron pipes put in the tuyere holes and rammed around into position with ganister and then left in during the blow? What is the advantage of that?

Mr. Robinson.—The advantage I have found was that the pipes kept the ganister more solid around the tuyeres. In the old practice, where the pipes were removed, there was a more or less ragged edge on the inside next to the metal, and consequently that would burn off more quickly than it should, but ramming the pipes into position with ganister and leaving them there, gives you a pretty solid bed condition there that stands up better than the old way without the pipe.

Mr. Jameson.—May I ask Mr. Robinson if he finds the blows quieter with one and a quarter to one and a half per cent silicon to the vessel or to the cupola? Is the blow quieter in that case than where you use say two or two and a half per cent, or about a middle range?

Mr. Robinson.—Well, that's a question that depends a good deal on the shop conditions. As I have stated, if you can work rapidly enough, I think it is possible to use one and a quarter or one and a half per cent silicon. In our regular practice, where we use 30 per cent to 40 per cent scrap, we would charge 1.50 per cent to 1.60 per cent silicon into the cupola; and then again, when we felt that we were going to work slowly, we would charge up to 1.70 per cent and 1.80 per cent into the cupola.

Mr. Stoughton.—In regard to the matter of the pipes, I think there's a further advantage in using them for the tuyeres, and that is it cuts down the fluxing effect of oxide of iron on the tuyeres. The lining at the tuyeres will oxidize a great deal more than at other points, for the reason that immediately the blast strikes the metal, it forms oxide of iron and that is going to flux the sand

lining at once. In many standard bottom blown Bessemer furnaces they ram coke breeze in with the lining just for the purpose of deoxidizing the iron oxide that is formed and preventing its fluxing the lining. It seems to me that the iron pipes are a little bit in the same direction. As regards the quietness of the blows with one and a quarter per cent silicon, it is not clear to me why they should be any quieter with one and a quarter per cent silicon than with two and a quarter. I do not favor high silicon; I favor low silicon every time and rapid work, but I was present yesterday when four blows were made with two and a quarter per cent silicon in the cupola; I suppose it was about 1.95 per cent or 1.90 per cent in the converter, and I never have seen any quieter blows than those four. Now do not let this be misunderstood as an argument in favor of high silicon. I favor low silicon, but it is not clear to me that the low silicon makes the blows any quieter.

Mr. Robinson.—I fear that if we discuss the question of silicon we will be here all day, so perhaps it would be wisest to close the discussion at this point.

DISCUSSION ON MR. R. A. BULL'S PAPER ON "THE ECONOMIC SIDE OF THE TWELVE HOUR SHIFT IN THE STEEL FOUNDRY."

Mr. Ploehn.—I was talking with Mr. Bull last spring, when he visited our plant, and the question discussed in his excellent paper came up. We changed our furnace men to an hourly rate instead of the usual daily or monthly rate, as they have in some plants, and in this way we fixed the rate per hour so that we could allow certain men to go home when their furnace was tapped, at least two to four hours sooner than if they should stay around just to put in the day. We usually worked this in the following way: The first helper or the man in charge of the furnace would stay and the second and third helpers would go home, possibly at four o'clock or even three o'clock, whenever the furnace had the last heat out, the bottom was fixed and the furnace charged for the next heat. In doing this, our company, I think, saved a little; probably not to any great extent, but saved a little in wages and at the same time gave the men shorter hours for the week. Sometimes they would be compelled to stay possibly twelve hours, but on an average they averaged about nine hours, which was just another scheme of trying to shorten the hours and maintain the efficiency, the men knowing that they could go home if their work had been done and the furnace could be taken care of by possibly one man instead of three. This is possible with the working of two furnaces, because, in case of an emergency with one, the men on the other furnace can always help out. With a single furnace, I do not see how it would work out so well. Our men appreciate it and our working conditions and our results, although we have not tabulated them, have shown it to be better. Moreover, there is more intelligence shown and we get more suggestions from the men since the time than we had before. The hourly rate was fixed so that the average was based on ten hours instead of twelve, so we divided the daily rate by ten hours instead of twelve. It actually figured

out a little over nine hours. Now, in some plants, this might be a solution of a method of shortening the hours and putting the men on an hourly rate instead of making three eight-hour shifts. We could not do this at the time very well, because we did not have the men broken in to be able to make three shifts, so we worked it out in our own way and it came out very nicely.

DISCUSSION ON MR. J. F. LINCOLN'S PAPER ON "ELECTRIC WELDING."

Mr. Kreuzpointner.—One of the virtues of an electric weld is found in the fact that it prevents the deterioration of the material on either side of the actual point of contact of the welded parts. That is to say, whenever any welding is done in the ordinary way, you cannot possibly avoid heating the ends back from six to eight inches to a part which afterwards is not touched by the subsequent hammering or rolling in order to complete the weld. The effect of this heating of the parts behind the weld, which is not removed by subsequent hammering, weakens the part to such an extent that it is even weaker than the weld itself. I remember a case some eighteen or nineteen years ago in a Colorado mine, when they were very much troubled by the breaking of stamp stems. These stamp stems had to be welded repeatedly and they broke very rapidly. I had nothing to do with the matter officially, but purely incidentally it came under my observation and I was asked for a suggestion. I advised having those stamp stems heated or annealed afterwards so as to remove the inequalities of the structure caused by the heating of the different parts behind the weld. The structure changes to such an extent that sometimes it is left entirely crystalline, and unless there is stock enough left to hammer it down and break up that crystallization, it will certainly weaken the part behind the weld. One of the advantages, other things being equal, of an electric weld, is that it avoids to the largest possible extent this defective heating which changes the structure behind the weld and weakens the material considerably.

DISCUSSION ON MR. C. H. GALE'S PAPER ON "TITANIUM IN MALLEABLE CASTINGS PRACTICE."

Mr. Kreuzpointner.—I would like to ask whether any bending tests were made in addition to the tensile tests? Permit me to say that I understand by the bending test the ability of bending around (doubling over), and in the transverse test there is only a limited amount of deflection taken. In my long years of experience, I have found that a bending test with alloy steel very often shows more than either the transverse or the tensile test. That is the reason I asked the question. In other words, if the ductility is sufficient, the bending test will at least allow a bending of 45 to 60 degrees. Experiments were made years ago with different alloying materials when they came into use; when aluminum, for instance, made its appearance thirty years ago, then vanadium, chromium, nickel and all those alloying elements came in, and I found that a bending test very often showed more than the mere transverse or tensile test; that is, it showed to what extent the viscosity of the metal allowed it to adjust itself to the shocks and requirements of the forces that tended to break the metal.

The Secretary.—I might perhaps add in explanation that Mr. Gale made the tensile tests at his works and made the transverse tests at my home. Suppose we had a flat bar of malleable and we undertook to bend it in the center. If we got an inch bend on a half-inch bar, it would be doing very fine. Those test bars would bend 1.8 inches and then fail. I have gotten as much as 2½ inches, but that was rare. You cannot bend malleable iron to the extent you bend steel or wrought iron to get that bending test you speak of, because you will quickly have a failure. It has not got ductility enough to get the value of the bending test you speak of. The metal contains almost four per cent of carbon and it is a net work of steel with the carbon in between, so that when you begin to bend it, the lower fibres part. We have to take the transverse test because it is hopeless to try the bending test on it, the material won't stand it.

DISCUSSION ON MR. C. F. DUDLEY'S PAPER ON "SOME THOUGHTS ON THE FOUNDRY PROBLEM."

Mr. Kreuzpointner.—Here we have a practical example of the importance and value of continuation schools. In all my inquiries, whenever I go to any city, whether East, West or North, I have found the objections by foundrymen and molders, referred to in the paper, in regard to the education of the boys to the wrong trade. In other words, they are so conservative that they cause a great deal of waste and annoyance in the everyday, practical running of the business of a foundry. I do not know and do not care to inquire why it should be that the molders always raise so much objection, but teachers universally, on the Pacific Coast as well as in the East, inform me that the greatest objection they find to their work is from the molders and foundrymen. Yesterday I visited a continuation school which is established practically by the city of Buffalo for the training of backward children. They take children thirteen years of age, who are not advanced beyond the sixth or seventh grade in the elementary school, and put them in that school out on Niagara Street among the foundries and in that neighborhood there where they thought they could do most good. Now then, I found that there they get an elementary education, a continuation of the subjects that were given them in the elementary schools, and woodwork and pattern-making. Now the point I want to make is this: in order to show them the relation of their work as pattern-makers to the practical work of making a mold and casting, they have a heap of sand there, have regular molds and flasks and a very small furnace for melting lead. They show these boys in that continuation school how to handle the sand and try to explain to them its nature. Now, here is the practical value of such a school. If there were more such schools, and if the foundrymen would take a hand and form a committee and go to the School Superintendent and say, "Here now, we are willing to co-operate with your schools

and visit them, and co-operate with the teacher." In that way, in a very short time, in three or four years, a lot of boys who are prepared for foundry work would come from those schools, free from the prejudices that molders have now, because they would go in the shops already prepared with the proper knowledge which they probably never will get in the shops surrounded by the old, conservative men. Here is a practical example of the value of a continuation school of a practical kind. (Applause.)

Mr. Miles.—In line with this subject, I think it might be of interest to know that in Buffalo here some three years ago, we were figuring on a technical, or rather, an apprentice school for boys to learn a trade, and the convention hall in which we have an exhibit now was considered at that time for the purpose, and there was a great deal of opposition on the part of working men, primarily union men, to using the building for that purpose, or to having such a school, their claim being that it was simply teaching boys to learn a trade and take positions away from the older men. In other words, it was another attempt to limit apprentices. The National Foundry Association some years ago established a school, as you know, in Indianapolis, and attempted there to teach young men the molding trade in a proper way, so that they would grow up to be high class mechanics, foremen, etc., and that didn't succeed and met with the united opposition of union labor in Indianapolis. The boys were criticised so much and really called scabs by the men there, that it was difficult to get boys at all; so this is a problem that is not easy to solve and I would be glad to hear more on the subject.

The Chairman.—I would like to say that as far as our establishment is concerned, we have to-day a little over fifteen per cent of our molders who were our apprentices. We have between seven and eight per cent of boys with us to-day whose fathers worked for us before. We have a course of three years or four years and give them a thorough education in core making, bench molding and molding on the floor. Our line, which is valves and fittings, is rather a particular class of work and we have got to have the best skill that we can possibly have, and we have met with a great deal of success by taking the boys and using a little care with them and in only one or two cases have we found, after a two years' apprenticeship, that the boy was not taking an interest

in his work, or that he was dull or something of the kind, and we have then dropped him. We make an agreement with all the boys, or, if the boy is a minor, with his parents. It is quite a lengthy agreement and if any of you gentlemen would like to have a copy of that agreement, I would be very glad to send it to you.

Mr. Miles.—Do you find it necessary to pay more than you did a few years ago for these apprentices?

The Chairman.—No, sir.

Mr. Miles.—That does not prevail generally here; the wages paid these apprentices seem not to be satisfactory; we found that in most of the foundries they wouldn't stay; they would serve out part of the apprenticeship only and then leave.

The Chairman.—We have got an agreement in Pittsburgh that one foundry will not take an apprentice from another foundry. Our minimum wage is 67½ cents a day.

DISCUSSION ON MR. JOHN PLOEHN'S PAPER ON "OPEN-HEARTH DESIGN AND MANIPULATION AS APPLIED TO THE STEEL FOUNDRY."

Mr. Bull.—I think the very good performance of the furnaces described makes the description very interesting, and there are some points that have some novelty. One which I believe to be quite important and which should be generally recognized in shops making one grade of work, is the classification of scrap. A little reflection, I think, will convince anybody that that is a very desirable practice and one which must give better results so far as the amount of pig iron goes. There is a question I would like to ask Mr. Ploehn on a point that he has not covered, and that is touching the amount of fuel oil consumed per ton of metal charged.

Mr. Ploehn.—I do not have the exact figures with me. We have been pretty busy this year, and so I did not have much time to get all the data I would like to have had together. We have melted with as low as thirty-eight gallons per ton in these furnaces, but our average will run along about forty-five gallons per ton. That is not counting any Sunday heating. We charge that off as plant expense, but the actual melting of oil per ton will average about forty-five gallons. This is probably an average on more than a thousand heats. About the scrap proposition, as I said, we are making the same uniform analysis all the time, which in some shops of course is not the case, but for us we get scrap in the shape of springs, couplers, knuckles, and rails and every old thing. It accumulates that way in different railroad shops, etc. As we couldn't get one melt high and another soft, and for a time had quite a little trouble, we finally got the scrap all separated into classes with reference to the carbon content, for that is really, for time and heating, the controlling feature, but it is one of the things that gives more uniform results. So now we buy the springs in a separate car, rails in a separate car, and couplers and knuckles and any other scrap in separate cars,

and we can get it that way without additional cost. This makes it a much smoother and better proposition, and the chemist in charge of the furnace specifies for the springs and the rails and the pig iron and the shop scrap, so that it is not left to the yard men at all. We know definitely what we are putting in, and knowing that, we can get better and quicker results than if we just put anything on the floor.

The Secretary.—I would like to ask if Mr. Ploehn will explain about his sand preparation?

Mr. Ploehn.—We have also in this foundry a complete sand handling equipment for carrying the sand from the shake out floor to the sand machines and from them to the molders. We have found this to be a very great advantage, for the reason that the sand in the shake out hoppers has a chance to be stored sufficiently long to be cooled off. It is not used direct. The last hopper that is shaken out is used last, in a continuous operation. The whole installation is made up of conveyor belts, and in going over this proposition we looked at all kinds of mechanical conveyors and I am mighty glad that we picked out the belts, because, aside from sometimes getting caught or having accidents, they give very little trouble and have a very low up-keep cost, especially in comparison with any mechanical scrapers or reciprocating devices. Besides they take a minimum amount of power. We handle with about forty horse power a total of 500 tons of sand in twenty-four hours, and that is going some. The men at the sand machine—there are only three or four required there—and on the shake-out hoppers need only keep the flow of sand uniform so that it will not back up and stick. We have got to have men there to keep it fed, and watch the trippers that trip the sand from the belt into the bins. Our three movable trippers move back and forth the length of about 250 ft. and distribute the sand wherever it is wanted. One tripper is stationary and if some dry or wet sand should get on the sand belt which the operator of the sand machine could not control, this is discharged practically back into the same room where the sand machine is located and can be used over again. Before you get on to your distributing area you want a tripper so that you can take any sand off the belt that you do not want to get down to the molders—sand that is either too dry or too wet, which you are very liable to get in shut-

ting down or starting up the machine. As to the question of the conveyor system and its advantages over buckets, etc., I think there's no comparison between them at all. Still, you can always fall back on the old method of handling the sand with buckets when you have trouble or something happens to the belt. Of course with this installation the shaking out is all done in the pour room and the molding rooms are alongside the pouring room and all molds are transferred out. The molders do no shaking out; sand, flasks and everything is brought to them, and they work continuously all the time, regardless of whether there is a heat on the floor or not. That alone is an advantage which the conveyors can bring about, and which helps in making a strictly manufacturing proposition a good one for a steel foundry.

DISCUSSION ON MR. A. W. BELDEN'S PAPER ON "THE GOVERNMENT CUPOLA MELTING TESTS."

Note by the Secretary.—Mr. Belden's paper giving the results of elaborate tests on Cupola Melting made by the U. S. Bureau of Mines at the Pittsburgh testing plant will be given in a subsequent portion of this volume. Under the law, it may not be published until released by the public printer. As soon, therefore, as the pamphlet is issued by the Bureau of Mines, it will be immediately republished in these pages.

The discussion is given in the meantime, in order not to break the sequence of the convention reports.

Mr. West.—I would be very glad to have the Government extend their tests so that the exact action of the center-blast be demonstrated. Considering the results Mr. Belden has shown there would seem very material advantages to be gained by the use of the center-blast over the present system of melting.

The Secretary.—Mr. West's idea is right enough. The paper gives the proof of a central cone of coke that does nothing. Were we to introduce tuyeres into the center, at the same elevation as those in the circumference of the cupola, this central cone of dead coke would disappear, and melting be more uniform.

A Member.—Mr. Belden, as I understood it, performed this experiment simply on the small sized twenty-seven inch internal diameter cupola. Most practice in this country is on a larger cupola and with varied amounts of blast. I would like to ask Mr. Belden if he contemplates any further experiments or has any idea of obtaining from the experiments he did perform, what would be the result in the larger sized cupola?

Mr. Belden.—I think it would be unnecessary at this time to make any further tests. The question of the size of the cupolas would not change matters any as long as you use tuyeres. It

is simply a matter of forming that inverted cone. The size of the cone and the height to which it extends would depend entirely on the amount of blast used. If you run your cupola with the same amount of air each day, you will get, in a very short while, a widening out of the cupola at a given point, and that same point is the point at which the free oxygen gives out and you have the highest temperature. It makes no difference what the internal situation is at that point, it is shown by the action of your blast and the cutting of the cupola lining. You are therefore perfectly safe by keeping all melting above that point, as shown by the action of your blast and the eating out of the cupola lining. Keep all melting above that point and you won't have any effect from oxidation of the iron by the gases.

The Secretary.—These tests show the facts a good deal clearer on a small cupola than on a large one and Mr. Belden is right in saying that you can easily deduce what would happen in a large cupola from what happens in a small one.

Mr. Belden.—The results seem to show that penetration of blasts is entirely unnecessary, because the central part of the coke bed does not burn anyhow; you simply have a burning around this cone. All we need is the volume of air, and if you get the proper amount of air inside the lining you will get iron out of the bottom and in proper condition.

The Secretary.—I don't know; I don't feel quite sure about that; while the penetration doesn't cut any figure in the lower portion of the bed, I think there ought to be a relation between the volume of air and its consequent penetration and the size of the cupola.

Mr. Belden.—There isn't any question but what there is a relation between the penetration and the height of the cone.

Mr. Anderson.—I should like to ask a question in regard to the charge of the cupola. In putting in the bed, is it wise to carry your coke right up through the melting zone after you have found out where your cupola widens and does its melting? Is it proper to fill that widened space with coke and put your charge on top?

Mr. Belden.—The idea would be to charge your bed and put enough coke above the point where the oxygen gives out so that this amount of coke will just melt the iron above it.

The Secretary.—If you keep above the danger line. For-

tunately it happens that at that line the temperature is about 3900° F. theoretically, and there is quite a distance you can go up before you get into a temperature too low. The German experiments have shown that they can still melt iron eighteen inches above that line. You had best start to melt four to six inches above this danger line, but you must not get below it. So I think I'd say that this line plus four or six inches of coke and then small charges to keep it from going too low. This is shown in practice by getting your first iron between eight and ten inches.

Mr. Brown.—I understood the gentleman to recommend the elimination of upper tuyeres; does that hold good in large sized cupolas and long heats?

The Secretary.—Yes, if you get your bed right by observing when the first iron comes and then watching your melting rate so that it produces the same amount of iron all the time.

Mr. Brown.—Then, under all conditions, the upper tuyere is unnecessary?

The Secretary.—I was in favor of the upper tuyeres when I was younger, but I am getting away from it. When I find an upper row of tuyeres, I shut them nearly all off just so the open ones do not interfere with the position of the melting zone. If you have the upper tuyeres all open, you are apt to get too wide a melting zone.

Mr. Belden.—I can't see any benefit in the upper tuyeres. The temperature is high enough to melt anything you can put on top of the bed in the cupola if you have got the proper volume of air going up through the bottom tuyeres.

The Secretary.—I am inclined to agree with you, but I have often found the lower tuyere area is entirely too small.

Mr. Brown.—What relation between the tuyere area and the area inside the cupola did you find to be most satisfactory?

Mr. Belden.—We didn't go into that at all. We wanted to take a cupola used under commercial conditions and follow it through, not as a matter of scientific work, but we wanted to do it under the same conditions the average foundryman did in his cupola, so we simply took a thirty-six inch cupola and lined it to twenty-seven inches.

Mr. Brown.—Then you did not determine the relation between the inlet pipe and the tuyeres?

Mr. Belden.—No, only I knew that the cubic feet of air I was sending out of the blower had to go into the cupola. We tried a fan first, but it was impossible to measure the amount of air blown in, and since the amount of air was the determining factor, it was absolutely necessary to go to some form of apparatus that would give us a definite knowledge of the amount of air going into the cupola.

The Secretary.—When you begin to figure this up you will notice that, no matter whether you have a big ratio of tuyere area to cupola cross section or a small ratio, it doesn't make a particle of difference, for you've got to put the proper amount of air through. If you have a small tuyere, it will shoot through very fast. If you have a large tuyere, it will go through more gently, but you must get the wind through it. As it makes a difference in the shape and position of the dead cone of coke, it is best to have a definite relation of size of cupola and air blown in to get the best melting results.

Mr. Anderson.—We use Collier cupolas and put in as many extra tuyeres as we can. We put in four extra tuyeres, increasing our tuyere area by sixty per cent, and we found, after going through all sorts of trouble, that to be the most satisfactory arrangement. Where you want more hot air, don't use your upper tuyeres at all; use a fan.

The Secretary.—We might ask Prof. Hein to tell us what they do in Germany. They have one continuous tuyere all around, don't they?

Prof. Hein.—Yes, sir.

Mr. Anderson.—The point I would like to ask of Mr. Belden regarding the delivery of air into the cupola, is what he considered the difference between delivery by a fan and by a positive blower —whether or not he would be likely to run up against snags if he did the same with a fan as with a positive blower?

Mr. Belden.—That is a question of practice in different foundries that will have to be taken care of at the foundry itself. It would vary in different places and would have to be worked out at each particular foundry.

Mr. Anderson.—Would the same practice be detrimental with a blower that we are now using with a fan?

Mr. Belden.—I should say not, if you had tuyeres in the bot-

tom of the cupola. As I understand when you use a fan, you shut off the air when you are melting, along towards the latter part of the heat. We do that because the melting of the last part of it does come down so low in the cupola that you're obliged to shut off the air or oxidize everything you've got in there. If you can keep the melting zone at the proper height throughout the heat it doesn't make any difference. The idea is to keep the same volume of air flowing in there from beginning to end; you may save a little bit of coke at the latter part of your run, using the fan, but you would merely confirm what I have said when you shut off the air, because you are reducing the base of that cone as you shut off the amount of air to be delivered by your fan.

The Secretary.—I am very glad we have had this paper of Mr. Belden's, because it gives us the scientific basis of what we have been considering a common sense method of working. Such tests have been made in Germany on the blast furnaces, but in this country we have to-day the first scientific basis for actual facts to go by, and Uncle Sam has paid the bill—which is better yet.

Mr. Belden.—I might say one more word, that Uncle Sam will be very glad to pay a further bill if the proper problem can be put up to the bureau for solution.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

THE ESTIMATION OF PIG IRON.

By **J. Kail**, Manager of the firm of Ganz & Co. Danubius, Budapest.

(Translated from the German by H. Borns.)

Two methods are at present in use for estimating the quality of pig iron and for grading it: the one depends upon the chemical analysis, and the other upon the appearance of a fresh fracture. Within the limits in which other elements occur in pig iron these elements affect the appearance of a fracture in the following ways:

P and Cu have no influence at all. S does not cause any change as long as its percentage remains below 0·1 or 0·12. Higher percentages of S diminish the capacity for taking up carbon and diminish the separation of graphite. (in pig iron which is poor in manganese this effect of S is noticed at lower percentages of S already.) The fracture assumes a finer grain, becomes dull and ash gray. So high sulphur contents are, however, rare in pig iron.

Mn raises the capacity for taking up carbon, but it prevents the separation of graphite and favours the formation of a fine-grained fracture. The effects are the opposite of those of S, but comparatively so small that the Mn contents cannot be estimated from the appearance of a fracture.

Si counteracts the absorption of carbon, but it strongly favours the separation of graphite; the more Si is present with a given carbon percentage, the more carbon will be separated as graphite and the coarser will be the grain, and the greater the metallic lustre of the fracture.

It is thus carbon that is the element which is most strongly influenced by the presence of the other elements. With higher

carbon percentages the separation of graphite increases, with lower carbon percentages it diminishes. But since the carbon contents do not vary so much as those of silicon (the usual limits are: carbon 3 to 4%, and silicon 1 to 3·5%), the influence of carbon is relatively unimportant, and the appearance of the fracture does not admit of estimating the carbon percentage.

The other elements Co, Cr, Ni etc. are so rare and present in so small quantities in pig iron that they need not be considered in this discussion.

Si would then be the only element as to which conclusions can be drawn from the fracture. More correctly expressed, silicon is the only element which influences the appearance of the fracture to such an extent that the quality of the pig iron can be judged from it. Even in this respect the estimation is unfortunately unreliable, since other factors also influence the segregation of graphite which is the chief factor for the appearance of the fracture.

When the pig is tapped from the blast-furnace at a high temperature, it will, after cooling, display a coarser grain than when it was discharged at a lower temperature, presuming equal conditions of cooling. When the pig is rapidly cooled (as when it flows into metal moulds or when water is poured on it), the dissolved carbon in the molten iron will partly be fixed as hardening carbon, the separation of graphite will be small, and the grain will be fine. When the cooling is slow, on the other hand (as when the molten metal flows into sand), the graphite separation will be favoured, and the grain will turn out coarse.

Thus it may happen, for instance, that a pig containing 1·5% Si, slowly cooled, will show a much coarser grain than a pig with 2% Si, rapidly cooled. In such cases the grading or quality estimation from the appearance of the fracture would be wholly misleading. We expect a pig to be gray, even when several times remolten, or to be originally rich in graphite.

The percentage of graphite depends, as is well known, in the first instance upon the Si contents, and the Si partly passes into the slag by oxidisation. A higher percentage of Si is hence an advantage, and in general such pig will be more valuable, since it can be mixed with cheaper scrap (old castings).

It results then that the appearance of the fracture of pig is differently and oppositely influenced by the presence of various

elements as well as by different treatments; to such an extent, that the quality, so far as the Si contents are concerned, cannot safely be estimated from the appearance.

It would, therefore, be desirable that this method of making an estimation from the appearance of a fracture — though certainly very convenient and expeditious — should altogether be discarded as unreliable, and that chemical analysis should be exacted in its place.

Chemical analysis is all the more to be recommended, since it does not involve any material difficulties. Chemical analysis can, at the present time, avail itself of methods which are perfectly reliable, expeditious and uniform.

A blast-furnace is rarely tapped more than 8 times in 24 hours, and an experienced works-chemist can easily conduct 10 Si determinations within 3 hours. It is hence possible to grade the output of the furnace of one day at very small cost with perfect accuracy. The general adoption of this method could be combined with another, not less important object, a uniform procedure as to grading.

In this field extraordinary want of system, uncertainty and confusion prevail at the present time. There are, for instance, blast-furnace works which supply pig of quality I, II and III according to the fracture estimate; others which offer quality I and III, others again supplying quality I, II, III, and IV. We find works which distinguish between light-gray and dark-gray pig, and others which speak of fine, medium and coarse-grained pig.

The various designations applied by different firms do not at all concord. The Si contents of various kinds of pig, going by the same grade, differ, or more precisely expressed, the I quality pig of furnace A contains, e. g. from 2·8 to 3·2% of Si, while the I quality of B contains from 2·5 to 3·0% etc. That state of affairs cannot be tolerated.

If the quality-estimation according to chemical analysis should be accepted, uniformity as to grading could easily be secured, for example:

Pig rich in Si	Si = above 3%
No. I	Si = 2·6 to 3%
No. II	Si = 2·1 to 2·5%
No. III	Si = 1·5 to 2%
Pig poor in Si	Si = 1·4% and less

or simpler:

Pig No. I	Si = above 2·6%
No. II	Si = 1·6 to 2·5%
No. III	Si = 1·5% and less.

This proposal concerns the ordinary pig of the market.

If accepted the specification of quality could be rendered uniform and be simplified to a remarkable extent.

The diverse special kinds of pig which are brought on the market — though in unimportant quantities — are characterised by their abnormal percentages of the one or the other element and are designated in this way.

Conclusion.

The Appearance of the Fracture does not even admit of making a reliable estimate of the Si percentage. The other elements like C, Mn, S, P, Cu, which materially affect the quality of the pig and hence also the quality of the casting, its strength, density, behaviour when machined etc., can only be determined by chemical analysis. The estimate based upon the appearance of the fracture is hence unreliable and therefore inadmissible.

Summary.

The Author recommend the adoption of chemical analysis for the valuation of pig instead of the estimation from the appearance of the fracture.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

ON THE INFLUENCE OF THE SHAPE OF THE BAR AND OF THE TREATMENT OF THE METAL UPON THE RESULTS OF NOTCHED BAR IMPACT TESTS.

By **A. Schmid,** Chemist to Messrs Escher Wyss & Co., Zürich.
(Translated from the German by H. Borns.)

When I attempted to incorporate into the acceptance tests for certain kinds of mild steel, such as iron for screw bolts and rivets, the work done in rupture in impact tests, in accordance with the resolutions of the fifth Congress for Testing Materials, held at Copenhagen in **1909**, I was confronted by certain difficulties caused by the large dimensions of the standard bars used in carrying out these tests on a practical scale.

The resolution also permits of making use of small bars of 10×10 mm cross section. These bars, however, appear to me unsuitable for acceptance tests on account of the very small radius of curvature of the notch, $^2/_3$ mm, because it is difficult to effect this boring in hard materials with sufficient accuracy and to control this opperation with the expedition and realibility desirable in acceptance tests.

We therefore agreed upon a test bar of 10×10 mm cross section, 2·5 mm depth of notch, and 1 mm radius of notch-curvature, the style of test bar which Prof. Schüle had already recommended to me on previous occasions.

Sufficient experience as regards this shape of test bar not being available, at least not for the purpose of basing acceptance tests upon them, I undertook on behalf of Messrs Escher Wyss & Co., of Zürich, the research which is described below. The objects of the test were to elucidate the following questions:

1. In what way are the results correlated when experiments are made

a) with a standard bar of a cross section of 30 by 30 mm, 15 mm depth of notch, and 2 mm radius of curvature, with a distance of 120 mm between the knife edges;

b) with the test bar, which is applied by preference in the Federal Testing Institution at Zürich, of a cross section of 20 by 20 mm, of a depth of notch of 5 mm, and of a radius of curvature of 2 mm, the span being 120 mm;

c) with a test bar of a cross-section of 10×10 mm, 2·5 mm depth of notch, and 1 mm radius of curvature of the notch, the span being 60 mm; and

d) with the same test bar, the span being 120 mm.

The series of tests d was undertaken, because in many steel works pendulum hammers of the invariable span of 120 mm have alone been installed.

2. Are the variations between the results obtained with the same material greater with a small specimen than with a large test bar? Are they perhaps so large that the application of a small standard bar would be questionable for acceptance tests?

3. Can the test bars, instead of being shaped in the cold from the rolled material, directly be forged to the respective dimensions —and this without applying any specially careful thermal treatment— such that this expeditious and convenient mode of procedure will not impair the reliability and the applicability of the method?

Professor Schüle very kindly placed the fall-hammer machine of Amsler-Laffon of the Federal Institution for Material Testing in Zürich at my disposal for these tests. This machine was described by him in detail at the fifth Congress in Copenhagen. I have further to acknowledge the assistance of Mr. O Brunner, Departmental Chief in the Federal Testing Institution.

How the Experiments were carried out.

So far the experiments have only been made with two mild steels of different hardness viz:

1. One rod of Siemens-Martin mild steel, rolled to a diameter of 44 mm, of a tensile strength of 38·7 kg and of 27·5% elongation.

2. A rod of Siemens-Martin steel, rolled to 40 mm diameter, of a strength of 47·9 kg and of an elongation of 28%.

Each rod was cut into pieces which were consecutively numbered for prepared specimens in the following ways:

from Nr. 1, 9, 17 etc. the shape a (30 by 30) was cut by the plane in the cold
2, 10, 18 „ „ „ b (20 „ 20) „ „ „ „ „ „ „ „
3, 11, 19 „ „ „ c (10 „ 10) (span 60) „ „ „ „ „ „ „ „
4, 12, 20 „ „ „ d (10 „ 10) („ 120) „ „ „ „ „ „ „ „
5, 13. 21 „ „ „ a was forged
6, 14, 22 „ „ „ b „ „
7, 15, 23 „ „ „ c „ „
8, 16, 24 „ „ „ d „ „

Seven specimens were prepared from each style of bar and were evenly distributed over the whole length of the respective rod I ensure by these means that, even if the homogeneity of the material should be defective, the mean values resulting from the separate shapes and even the deviations observed should be intercomparable.

In addition to these tests a special brass of the firm of Escher Wyss & Co. has been examined in the same way, both in round compressed rods and in the hard drawn state. In this latter case, however, I have confined myself to a comparison of the rods which had been shaped in the cold, and on account of the small thickness of the section I did not experiment with any standard rod of 30 by 30 mm. The results obtained are tabulated below. The separate corresponding values have been joined by straight lines, and the discrepancies between the different specimes have thus been brought out in a striking manner. In each curve I have also marked the resulting mean value.

The ratios between the means resulting from the experiments with specimens of different shapes are marked in the following table.

	means	Martin mild Steel		Martin Steel		Special Brass	
		planed	forged	planed	forged	com-pressed	drawn
a : b	0·987	0·97	1·01	0·85	1·12		
a : c	1·44	1 53	1·46	1·24	1·52		
b : c	1·51	1·58	1·43	1·46	1·36	1·62	1·63
a : d	1·62		1·85	1·30	1·80		
b : d	1·65		1·82	1·53	1·62	1·49	1·80
c : d	1·11		1·26	1·06	1·19	0·92	1·10
a forged a cut with plane		1·22		1·51			
b „ b „ „ „		1·16		1·14			
c „ c „ „ „	1·23	1·28		1·23			
d „ d „ „ „				1·08			

Conclusions.

Definite conclusions of general valency cannot yet be drawn. For the number of independent values determined is too small so far, and I need not point out that these researches have to be extendend to harder steels of higher carbon percentage and to special steels. Yet the results so far obtained permit of drawing certain conclusions as pointed out below, which must, however, not be applied to other materials.

1. The bars b of a cross section of 20 by 20 mm give practically the same values as the large standard bar. The resulting ratio is 0·987, or practically 1.

2. The results obtained with the small bar c of 10 by 10 mm cross section, with a span of 60 mm, yield, when multiplied by the fraction 1·44, approximately the same value as the large test bar for the same material.

When the knife edges are 120 mm apart, the value becomes a little smaller, and the factor is in that case 1·62. When we determine this factor by multiplying the ratio c: d (1·11) with that of a : c (1·44), a method which is perhaps safer in this case on account of the larger number of available determinations, the factor becomes 1·60. The agreement is thus very satisfactory.

3. The respective factors by which the values obtained with the small bars must be multiplied in order to yield results corresponding to the bars of the b shape, come up closely to the former; they amount to 1·51 when the span is 60 mm, and to 1·65 when the span is 120 mm.

4. The discrepancies between the several values found for one and the same style of bar are rather considerable; this circumstanc should be borne in mind when minimum values are fixed for acceptance tests.

It is, however, noteworthy that the discrepancies represent on average about the same percentages with small bars as with large bars.

5. The values are raised by 23% on an average, when the test bars are forged instead of being worked in the cold. It is curious that this percentage is not larger, when the bars are forged to the small cross section of 10 by 10 mm, than when forged to the large cross-section of 30 by 30 mm.

6. Although the forging was effected without any extraordinary care, and although the forged bars were allowed to cool in the usual fashion without applying any particular precautions, the forged test bars did not differ more from one another than the planed bars.

For the present the practical results of these experiments may be summed up as follows:

1. Test bars of cross-section of 10 by 10 mm, a depth of notch of 2·5 mm, and a radius of curvature of the notch of 1 mm are quite suitable for determining the specific work of rupture for acceptance tests. The bars should have a length of 80 mm, and the supports should be 60 mm apart; the notch is to be bored.

2. The values for the work done in rupture, obtained with these small bars, yield, when multiplied by the factor 1·44, approximately the value which would result from tests of the same material, made on standard bars, cross-section 30 by 30 mm, depth of notch 15 mm, radius of curvature of the notch 2 mm, span 120 mm; these standard bars cannot generally be applied for testing because of their large dimensions.

3. The bars may without hesitation be prepared in the desired dimensions by forging at red heat; a specially careful thermal treatment is not required. It must be borne in mind, however, that the forged bars will yield values which are about 23% higher than those obtained with bars which have been shaped in the cold from the rolled material.

Influence of the Shape

Siemens-Martin Mild Steel Rod. ∅ =

I.

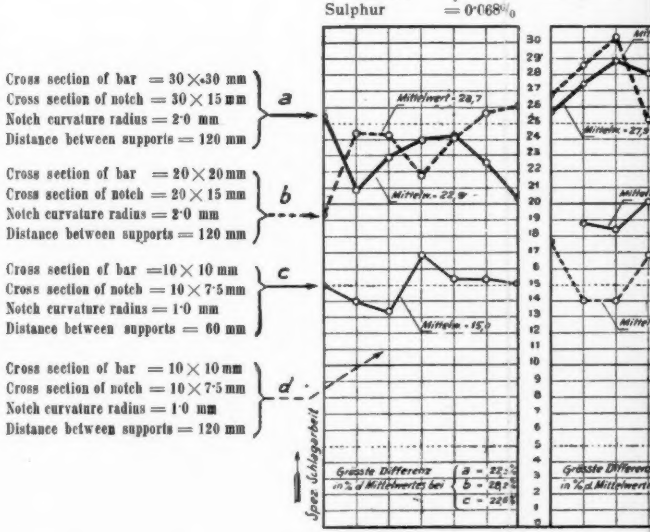
Specimen shaped in the coll.

Carbon percent = 0·08%
Silicon = traces
Manganese = 0·77%
Phosphorus = 0·036%
Sulphur = 0·068%

II.

Specimen forged

Elastic limi =
Tens le strength =
Contraction of area =
Elongation =



of the Shape of the Bar on Notched Bar Impact Tests.

d Steel Rod. ∅ = 44 mm.

II.

Specimen forged to dimensions.

Elastic limi = 25·7 kg/mm²
Tens le strength = 38·8 kg/mm²
Contraction of area = 62%
Elongation = 27·5%

Siemens-Martin Steel Rod. ∅ = 40 mm.

III.

Specimen shaped in the cold.

Carbon percen = 0·27%
Silicon = 0·03%
Manganese = 1·06%
Phosphorus = 0·032%
Sulphur = 0·027%

IV.

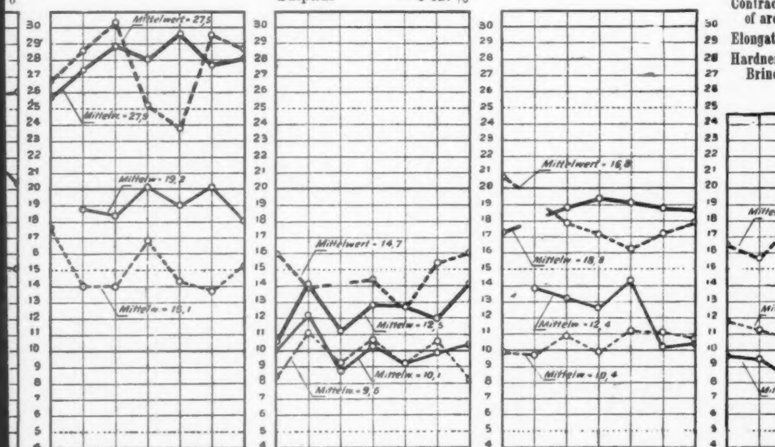
Specimen forged to dimensions.

Elastic limit = 27·0 kg/mm²
Tensile strength = 47·9 kg/mm²
Contraction of area = 31·4%
Elongation = 28·0%

Pres

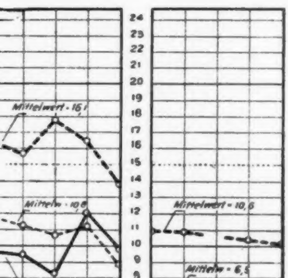
∅

Elastic limit
Tensile strength
Contract of area
Elongati
Hardness Brinel



Special Brass.

V.	VI.
Pressed Warm	Hard drawn
○ = 32 mm.	from 32 mm to 30 mm
lastic limit = 13·3 kg/mm²	Elastic limit = 41·5 kg/mm²
ensile strength = 46·0 kg/mm²	Tensile strength = 58·2 kg/mm²
ontraction of area = 47%	Contraction of area = 51%
longation = 39·0%	Elongation = 20·0%
ardness after Brinell = 117 kg/mm²	Hardness after Brinell = 167 kg/mm²



REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

UTILITY OF A METALLOGRAPHIC NOMENCLATURE.

By **Félix Robin,** Paris.

(Translated from the French by H. Borns.)

No rule appears to have been indicated so far for the denomination of the constituents of alloys.

Up to the present each metallographer has designated an element by a name, a letter or a phrase, according to their determination. It results, that much confusion prevails at the present time, and that the same element is designated in different ways by different authors.

In order to preveut that complete confusion overtake us in the future, it might perhaps not be useless to suggest a unique system, logical as far as possible, for designating the constituents of alloys.

The different actual systems may be reduced to three. They are based upon the use of proper names, of names indicating properties, and of symbols.

The use of proper names has been taken over from the descriptive natural sciences. The mineralogical nomenclature is based upon this system. In this science the infinite variety and the great complexity of every natural object evidently render it very difficult to ensure that the appellations should always recall the properties, and the notation by ciphers and symbols is particularly difficult. If we consult mineralogists, they appear to be unanimous in recognising that their actual nomenclature is most defective. They regret that the habit, which a considerable period of the use of the present mode of designation has sanctioned,

should up to the present have been stronger than the attempts of reaction.[1]) They would advise a science like metallography, which is still very young, to adopt a rational nomenclature, as soon as possible whilst there is still time, and above all not to follow the example which they, the mineralogists themselves have given.

It would, moreover, be necessary to create a very large number of words ending in "ite", for which we should have to find names among the different scientists. Finally this somewhat arbitrary system exacts useless efforts on the part of our memory. Such a system, we submit, should not be employed except in the cases in which we cannot do otherwise.

The two systems which are alone rational, when the name is to indicate the character of the element, are the adoption of names indicating properties and notation by means of symbols.

Names which recall to us the properties would be suitable, if all the elements had been discovered and if all the properties been determined; but that is not so, and in giving a name to an element one may fear that there will soon be cut off from it another element, which might possess the properties of its predecessor in a still more accentuated degree. Finally, in the case of a great number of solid solutions of metals, we should have to look for a long time for a signal, really distinctive property.

A system of rational symbols should, it would appear, to a considerable extent be appropriate in metallography.

The form with which it should be invested remains to be determined. It is to this point that we desire to draw the attention of investigators, since we have not ourselves sufficient leisure to make enquiries in this direction.

Merely as hints we beg to offer a few tentative ideas which seem to come into our minds in the first instance.

I.

Let us designate the term solid solution by a letter. The metals or combinations, designated by their chemical symbols,

[1]) The Americans have recently suggested a nomenclature which has not found many adherents.

might be comprised by this letter indicating the solution of a second element in the first in a preponderating quantity.

The letter S might create a difficulty, at least in speaking, on account of the possible confusion with the compounds of sulphur. As it is, moreover, not generally established that there is syncrystalisation in these cases, very many authors prefer to call them mixed crystals. One could therefore, adopt the letter m as symbol for this last term.

The solutions of the metals MM_1 might hence be designated by the form MmM_1 The extreme percentages of the solutions might be indicated by indexes of m, and the saturated solutions might bear the term ms or m with the index of the percentage of the second metal.

In cases where a generalisation is possible one might allow the letter M to designate any metal whatever. (Cu m M for the α solutions of copper, Fe m M for the ferrites.)

The eutectics might be symbolised by e with or without an index placed in the same manner between the contituent elements. For the hardened constitutions the letter l might indicate the liquidus and the letter t the instability of the constitution or the hardened state. As indexes might serve the percentages or the critical temperatures.

II.

The hardened needle texture and its conditions of tempering can apparently not easily be designated in an analogous fashion without a regrettable length of terms. For this class alone we might then reserve the classical denominations: Martensite, Troostite, Sorbite at least, of at least, if, as we consider at the present time, the phenomena of the production and the transformation of the hardening structure in needles permit of generalisation. One should then have, for example, martensite, troosite and sorbite of aluminium bronze and of tin bronze.

Note.

In writing one might, if desirable, modify the type in order to designate the metals (for example *Fe* instead of Fe), if one wished to indicate the impure metals of metallography which are almost always solid solutions containing a small proportion of strange

elements. We could avoid in this way, for example, to have to designate ferrite by a complex symbol.

III.

One might also, as we have suggested, adopt, as the chemist does, the terminations "ase" and "age" for solutions or aggregates, and prefixes "meta" for constituents which are not in equilibrium. One would in that case no longer designate solutions, considering that all the elements of metallography contain something in solution. In each binary group the designation of the group could be made by a word composed of syllables, taken from each metal (cuprotin, cuprozinc &c.).

In spite of the divergence of the designations for certain complexes, it is evident that we should be able to arrive at some understanding with the aid of rational systems of indication. Whilst strongly preferring them to the mode of notation α, β, γ. . . a b c . . ., we should still be inclined to find many faults in the systems which have very hurriedly suggested in the preceding pages. Our sole object is to direct the attention of others to the utility of a nomenclature in metallography.

Summary.

The author would prefer to substitute, for the actual metallographic designations, rational symbols and to group as far as possible analogous constitutions such as those, for example, which characterise the hardened needle-texture and the texture of the annealed state.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

BREAK-DOWN TESTS OF METALS.

By **O. Boudouard,**

Docteur en Sciences, Lecturer on Metallurgy at the Ecole de Physique et de Chimie Industrielle, Paris.

(Translated from the French by H. Borns.)

Rupture of a metal is produced not only when the breaking stress is applied in one single instance, but also when the metal is submitted to tensions or compressions decidedly smaller than the breaking stress, all being of the same sense and repeated a sufficient number of times, or again when the metal is submitted to still smaller tensions and compressions provided that they act alternately in opposite senses. Now the resistance of metals to alternating stress is an essential feature for a great many industrial applications, in particular for parts of machines in which the stress changes at every instance in sense and in magnitude.

Mr. A. Guillet, Secretary of the Faculté des Sciences in Paris, established the two following facts two years ago, while studying the vibratory movements of metals: 1st. Under the same experimental conditions the damping of the vibrations of a U of soft iron is about three times greater than that of a U of soft steel; 2nd. The viscosity of the metal varies in accordance with the deteroration of the metal owing to the repetition of the alternating stress. Professor Henry Le Chatelier directed the attention of scientists and engineers to the problem which Guillet had attacked; the measurement of the damping indeed revealed a novel property of matter which was directly connected with the intimate constitution of matter, and the new method of testing — apart from its being economical and rapid — should offer the very great advantage that

it follows the deterioration of the metal as it proceeds, because this deterioration is manifested by a rapid and very considerable increase in the rate at which the damping of the vibratory movement takes place.

The use of the tuning fork, as suggested by Guillet, is not absolutely indespensable for this kind of testing. It is on the contrary, preferable to experiment with rolled rectangular bars, analogous to those which the works supply. The simplest arrangement is to grip

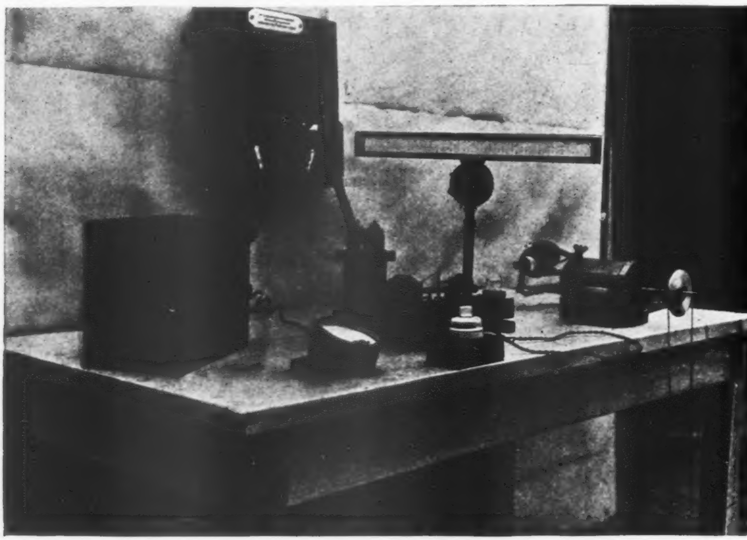


Fig. 1. General View.

similar bars, 20 to 30 cm in length, in a massive and rigid support; the practical difficulty is, however, to secure that the mounted bar has no free play, and that the mounting has no influence upon the damping.

Description of the apparatus.

The apparatus is intended to produce vibrations in the horizontal plane (fig. 1). The bar of metal to be examined (fig. 2) has the following dimensions: width 1 cm, thickness 0.6 cm; the bar oscillates over a length of 27 cm. It is fixed by one of its

extremeties in a sort of vice S rising perpendicularly from a bench B which is provided with a longitudinal groove along which the electro-magnet E slides which attracts the bar or rod. By the side of the bench, which is independent of the vice, is mounted a small

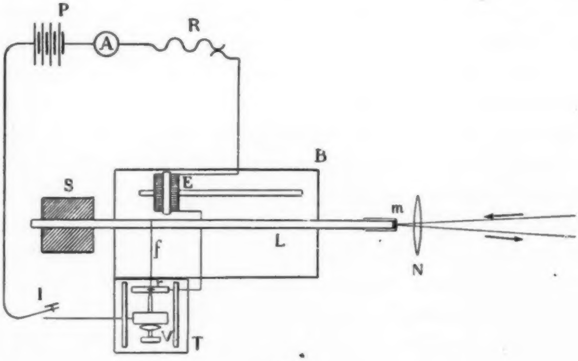


Fig. 2.

brass table T likewise grooved, being provided with two grooves along which the contact slides which is controlled by the vibrating bar. The vice which holds the metallic bar resembles a small rolling mill for hand operation, the cylinders of which have been replaced by jaws of hard steel which have most carefully been adjusted. These jaws form the seat for the bar in question (fig. 3). The lower jaw M is fitted with two studs G, which penetrate into two holes drilled into the base of the small mill so that M is firmly fixed; the upper jaw M′ bears the pressure of the two screws of the mill. The vibrating rod is by these means held immoveable over a length of 5.7 cm. The vice is solidly fixed to a table (of slate) by means of two angles of soft iron fitted with screw bolts. The bench B is secured in a similar way, and the table makes one body with the walls of the building. It is indeed very important

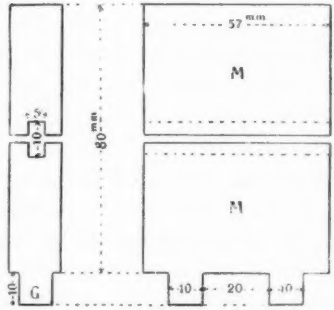


Fig. 3.

1

for this style of experiment to realise an absolute rigidity of the support of the vibrating reed, lest the vibrations be affected by external causes. The apparatus which I have installed at the Collège de France seems to satisfy this condition. By watching a horizontal mercury surface one can ascertain that vibrations of very large amplitude do not affect the support more than very slightly; anyhow, the mounting of the metallic bar in the jaws of the vice leaves no free play and does not play any part in the damping of the oscillatory movement, therefore.

The contact by means of which the vibrations are maintained is placed at about 9 cm from the fixed extremity of the rod. It consists of a vertical flat spring *r*, which forms the mobile terminal and which is connected with the rod by a thread *f* (of sewing cotton); against this spring *r* bears a screw V, the fixed terminal. The current interruptions are produced by the vibrating rod which actuates the flat spring *r*, because it keeps the thread *f* more or less stretched. The parts of the spring and of the screw between which the spark passes are protected by platinum; as the platinum contact on the spring disappears rapidly, it is preferable to substitute for it a blade of iron, 2 or 3 mm in thickness which has no value and can easily be replaced. The electromagnet acts on the rod at a distance of about 10.5 cm from the fixed end.

The current intensity can be measured at any moment by the ampèremeter A, and it can be varied with the aid of the resistance R; the current is furnished by four accumulators. The circuit comprises an interrupter I which can break the current of the electromagnet at once, when one wishes to study the damping of the vibrations of the metal under examination.

The maximum amplitude which is compatible with a given static intensity is immediately obtained, when the contact is so regulated that the ampèremeter marks half the static intensity. A few hundredths of an ampère suffice to produce a sensible vibratory movement. When one wishes to obtain displacements of the free end of the rod corresponding to a few centimetres, a current of several ampères will be required. The distance between the lateral surface of the bar and the extremity of the core of the electromagnet is about half a centimetre.

Readings of the amplitudes are taken with the aid of a narrow slit, which is well illuminated from some source or better directly

by the filament of an incandescence lamp; this slit is placed in the focal plane of a lens N, interposed between the transparent graduated scale and a small plane mirror attached to the end of the vibrating rod. The rays from the lamp traverse the lens, are reflected by the mirror, pass through the lens a second time, and then form an image on the scale which is in the same plane as the source of light. The mirror is fitted into a brass sheath which is pushed under hard friction over the free end of the rod. The lens is placed at a distance of about 1 cm from the mirror. With this arrangement deflections of the image of 30 cm and more can easily be obtained by using lenses of different focal lengths and by varying the distance between the mirror and the lamp. The amplitudes at different moments or, at any rate, the total length of the damping period can be measured with the aid of a chronometer; but the operation is very delicate. In order to ensure a greater accuracy and, above all, to avoid all personal errors it will be more convenient to photograph the damping curve on a cylinder which is turned at a known rate, once per minute e. g. One can at the same time register, once for all, the curve of the oscillations of a tenth-of-a-second tuning fork; in this manner the length of the damping period and the number of rod vibrations per second can be recorded. I have made use of a recording cylinder after Richard, 12 cm in height, on which a sheet of very sensitive gelatine-bromide paper is wound. The luminous slit is constituted by the filament of a Nernst lamp; the intersection of the vertical luminous image with the horizontal slit, guided along a generatrix of the second cylinder surrounding the first moving cylinder, determines the luminous point which acts on the photographic paper. Nernst lamps are to be recommended, since the vibrations are rapid both in normal movement and during the damping. Other lights are hardly powerful enough completely to register the normal vibrations and the damping curve.

Course of an experiment. — In each series of tests one registers the damping curve of the bar before it is made to vibrate, and then the damping curves at variable time intervals up to the moment of rupture; the different diagrams are afterwards compared with one another. The long-duration tests take place in periods of unequal lengths; sometimes the metal remains at rest for one day or several days between the recording of two successive damping curves.

When the curve is registered by a Richard apparatus which makes one revolution per minute, the length of the successive elongations cannot easily be measured with sufficient precision. We obtain in fact the curve-envelope of the vibratory movements without being able to distinguish the individual vibrations, and we can thus only determine the length of the damping period. When we then replace the clock work, which makes the cylinder complete one turn per minute, by another gearing which increases the speed about five fold, then the vibratory movement itself will be recorded, and the photograph allows us to determine both the amplitudes and the number of vibrations with sufficient accuracy. This gearing is very simple: an aluminium pulley is mounted on the shaft of the recording cylinder; in the hollow of the pulley lies a cord which supports an iron disc at its one extremity and a counter-weight at the other; in its fall the disc makes the recording cylinder take part in its movement, and this movement is kept regulated because the fall takes place within a test tube filled with water, the diameter of the tube being a little larger than that of the disc. In this way the recording cylinder is turned at a fairly uniform rate which can be adapted to the experiments. When a curve is to be recorded, the disc is raised to its upper position; it is then left to itself for a few seconds, after the shutter of the Richard apparatus has been opened; the current of the electromagnet is now interrupted by means of the device I have mentioned above. When the pulley has described one turn, which is easily ascertained with the aid of a mark, the shutter is lowered. One has afterwards only to develop the photograph.

In the photographs thus obtained the distance between the extreme points of the elongations constitute the amplitudes to be measured, and it is just at these points that the action of the light on the sensitised paper is maximum because the velocity of translation of the mirror is there zero. The amplitudes are measured with the help of a glass mirror which bears a scale divided into half-milimetres; this mirror is moved over one vibration-curve after another, and readings to a quarter of a milimetre can easily be taken. In order to enable the experimenter to count the number of the vibrations, especially near the end of the damping period, the mirror further bears a series of equi-distant parallel lines by means of which the mirror can be shifted through a known distance,

parallel to itself, starting from a reference point previously marked on the diagram.

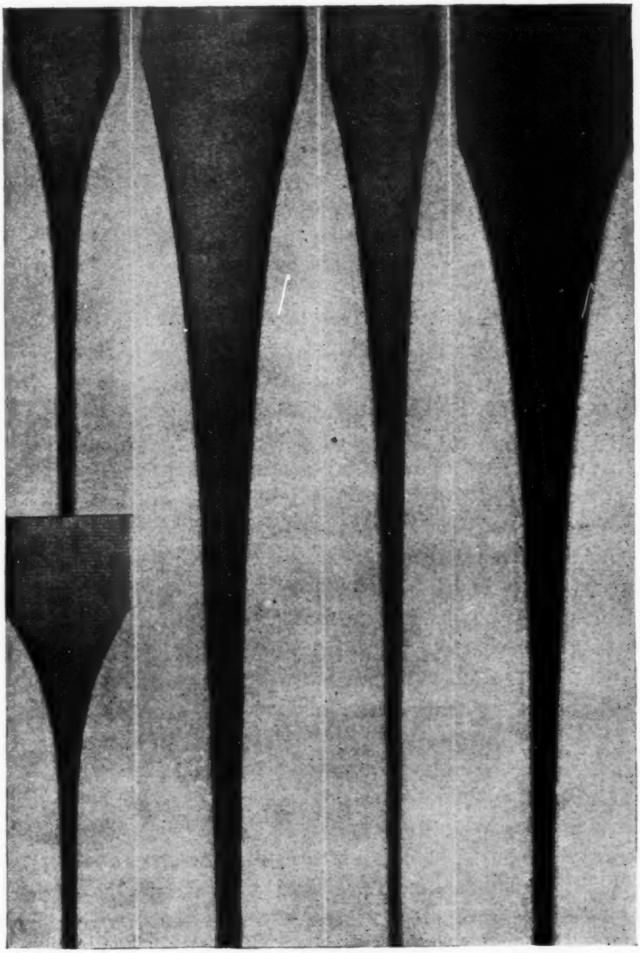


Fig. 4.

The total elongation of the free end of the vibrating rod is 3.5 or 4 cm, which corresponds to an angle of deflection of 6^0

or 7^0 between the extreme positions. About 30 double vibrations are counted per second. According to Chladni an oscillating rod having one end fixed and the other end free should give the note $ut_1 = 32.625$ double vibrations.

All the tests have been conducted in the air and at ordinary temperature. One has, however, to ask oneself whether the resistance of metals to alternating stress is not a temperature function. Very often metals are doing work at more or less elevated temperatures, and we know that the rupture of parts which are heated by the steam in engines cannnot be explained by a diminution of the toughness. Vibration experiments are now being conducted on hot metals in accord with the Unieux Steel Works.

Results of the experiments.

The tests were made with the following carbon-steels which Messrs. Schneider & Co. had placed at my disposal:

No. 1 . . . . Puddle iron.
2 . . . . Basic Martin steel, extra soft.
3 . . . . Crucible steel, obout 0.3 per cent of C.
4 . . . . " " " 0.6 " " " "
5 . . . . " " " 1.0 " " " "

As regards the precision of the method I have investigated, whether it was always possible to secure the same experimental conditions with regard to the clamping of the bar between the jaws of the vice on the one hand and the fixing of the vice to the table on the other. The discrepancies which I observe with respect to the first point are always distinctly smaller than those shewn by the diverse damping curves of the same metal; as regards the second point a defective fixing it at once recognised as such, because the damping of the vibratory movement is then almost instantaneous. The influence of the air resistance on the vibrations does not modify the general conclusions of this research; it produces an increase in the value of the decrement amounting to about $10^0/_0$; this figure is generally accepted.

In the table of the numerical results which can be found in the Bulletin de la Société d'Encouragement pour l'Industrie nationale (Dec. 1910, Jan. 1911) the different columns indiceat the number of vibrations, the elongations as measured on the photographs, the natural logarithms of these elongations, the natural

logarithms of the ratio of two elongations of different orders, and the corresponding logarithmic decrements.

The results may be summarised as follows:

Designation of the metal	Time during which the vibrations continued, up to rupture	number of vibrations
No. 1 annealed	18 hrs. 45 min.	1,995,000
2 annealed	11 „ 45 „	1,215,000
3 annealed	13 „ 15 „	1,431,000
— hardened	14 „ 15 „	1,512,000
4 annealed	6 „ 15 „	648,000
— hardened	1 „ 25 „	153,000
5 annealed	3 „ 25 „	369,000
— hardened	5 „	9,000
— hardened and reheated . .	no rupture after $26^1/_2$ hrs. >	2,862,000

In all these tests rupture of the metal is finally produced by the repetition of a great number of alternating stresses which were smaller than the breaking strength. It is known that a piece of metal, when submitted to a repetition of alternating stress, rising from zero as lower limit to a certain predetermined upper limit, will not fail even after an unlimited number of applications of the stress provided the upper limit remain below the primitive limit of elasticity; as long as this limit is not exceeded, the security of the part is not endangered. It is easy approximately to calculate the force corresponding to the action of the electromagnet capable of imparting to the test bar an equivalent flexion, and also to determine experimentally the practical elastic limit of the metals which are tested by vibrations; and this investigation will show that the bars have been broken although they were merely subject to stress below their elastic limit.

Finally with respect to the question of the damping of the vibratory movement, the results — contrary to what might have been expected when the research was started — do not on the whole appear to establish in any decisive manner, that the metal does undergo noteworthy transformations before breaking down, and that its alteration could easily be followed by comparing the rates of the damping of the vibratory movement at different instances. Nevertheless, we can keep count of the variations in the damping by determining the mean logarithmic decrement in each case; we then come to the same results as when considering the damping curves constructed by taking as co-ordinates the number of vibrations and the logarithms of the elongations.

Conclusions.

I. — In testing different specimens it is easily possible to ensure the same experimental conditions and to obtain measurements which are comparable with one another. One need not fear any defect in the gripping of the screws which fix the support of the fram to the table; for any such defect would immediately reveal itself by the character of the damping curves which would entirely differ from the other damping curbes. The time necessary for the rupture of a metal under continuous vibratory movement comes out practically the same in the differents experiments. In the case of steels containing about $0.3^0/_0$ of carbon, not of the same origin but of the same chemical composition, it is found that the break-down tests takes from $12^1/_2$ to $13^1/_4$ hours. This new method of testing metals by the study of the damping of the vibratory movement therefore admits of useful application for the purpose of determining their resistance to alternating stress.

II. — The vibratory movement, when sufficiently prolonged, leads always to the rupture of the tested metal, and the number of necessary vibrations varies, in the case of the half-hard and of the hard carbon-steels so far studied, in the inverse ratio of their carbon ratio. Puddle iron and extra-soft steel which have nearly the same composition (apart from the percentage of manganese which ranges between 0.050 and $0.400^0/_0$) and which also have the same mechanical constants, show a marked difference as regards the length of time required to effect rupture; puddle iron resists much longer than the extra-soft steel. Whether the 0.3 carbon-steel is annealed or hardened does not make any noteworthy difference. For the hard steel the hardening diminishes the length of the period, during which the vibrations have to be maintained to effect rupture, very noticeably. Reheating improves the quality of the metals considerably; a steel with $1.0^0/_0$ of carbon which broke after 3 hours 25 min. in the annealed state, and after 5 min. in the hardened state was not yet broken after $26^1/_2$ hours in the hardened and annealed condition.

III. — All the fractures of the broken metals will offer a similar appearance. We distinguish in them, even with the naked eye, lines of separation along which the rupture appears gradually to have taken place. The size of the grains varies with the zones, and this size appears particularly exaggerated in the hardened metals. Moreover, at right angles to the edges of the brocken section, lines aredi stinctly descernible which suggest a tearing apart; these

ines are not any longer than half the smallest dimension of the bar, and they do not show any regularity.

IV. — As regards the mechanical properties one should not overlook the great rise in the elastic limit shown by the puddle iron and the extra-soft steel after having been broken down by continued vibrations. It should also be accentuated that all the metals tried have been broken down, although they were exposed to stress that kept well below the elastic limit.

V. — The variations in the damping of the vibratory movement are in general too small to characterise a metal at different moments of the test. If it were possible to predict the exact moment of rupture, the comparison of the curve obtained a few minutes before the rupture and of the initial curve would furnish further interesting information concerning the state of the metal which has been vibrated; this seems to follow from the tests made with the metals 1 (annealed) and 4 (hardened), in which the damping curves taken 15 and 25 minutes before the rupture indicated that the damping had increased by about 50% above its initial value. But a fixed rule cannot be laid down; for nothing is known as to any new metal, unless the experiments are multiplied at very close intervals, which would render the method very tedious. I must, moreover, point out again that I have not been able to conduct the long-duration tests which I have carried out without interruption. The metal had to remain at rest for one or several days between the registrations of the successive damping curves; might there possibly intervene some factor which would influence the final results of the tests?

As regards the annealed steels, the damping diminishes when the carbon percentage increases. When we compare the extra-soft steel with the puddle iron of the same chemical composition and of the same mechanical constants, we find for the same duration of the vibratory movement that the damping of the puddle iron is by about 50% smaller than that of the extra-soft steel, but that it becomes almost equal to it a quarter of an hour before the rupture of the test bar, that is to say, $7\frac{1}{2}$ hours after the soft-steel bar had already been broken. The damping of the hardened metal No. 3 is inferior to that of the same metal in the annealed state; the opposite holds for the metals No. 4 annealed and hardened. Finally in the case of metal No. 5 the damping of the hardened and annealed metal, although it passes through a maximum, remains practically the same as that of the reheated metal.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

INVESTIGATION ON THE INFLUENCE OF THE SHAPE OF TEST BARS ON THE MECHANICAL PROPERTIES OF CAST IRON.

(Report of the English Members of Committee N° 1b on Testing Cast Iron.)

Presented by Dr. **J. E. Stead,** Middlesbrough.

Your Committee beg to submit the following report of their investigation on the influence of the shape of the Test bar on the Mechanical properties of cast iron as shown by Comparative tests made on the Standard Bars of English, German and American section. Two series of Cast Test bar were made at different foundries, one at Middlesbrough and one in London. Messrs. Richardsons, Westgarth & Co. kindly arranged after consultation with Dr. Stead to cast at their works in Middlesbrough the first series of bars of a good foundry mixture such as is commonly employed for good average castings. Four bars each of the English, German, and American standard test bars were cast all from the same ladle of metal; two in each were cast when about one fourth of the metal had been poured from the ladle and two of each when about three-fourths of the metal had been poured from the ladle. Mr. W. G. Kirkaldy of the firm of Messrs. David Kirkaldy & Sons undertook to carry out the Mechanical tests and all the bars were tested by him personally. The details of the results are embodied in Tables I & II, and the analyses made independently by Dr. Stead and Mr. Harbord are also attached. The transverse tests of the four German and four American bars have been calculated to the equivalent load of the English bar and are given in column marked "A". In each case one of the bars had a slight defect but eliminating three bars the maximum difference in load in the

Table I.

Results of Experiments to ascertain the Transverse Strength etc. of twelve Cast Iron Bars, received per Messrs. Pattinson and Stead.

Test No.	Description	Dimensions	Span.	Ultimate Stress	Ultimate Deflection	A Calculated Equivalent load upon English Standard Bar 1"×2" 36" span.	Appearance of Fracture
TT		inches	inches	lbs.	inch. mm	lbs.	
		B D					
4012	2"×1" Bars (Cast on flat) English Standard	1·13×1·98	36	2625	·36	2372	Sound
4013		1·07×1·99	36	2800	·37	2640	do.
4014		1·04×2·01	36	2610	·33	2484	Slight defect
4015		1·03×1·98	36	3100	·40	3068	Sound
			Mean	2784	·36	2641	
4016	$1^3/_{16}$" dia. Bars $25^1/_2$" long German standard (Cast horizontally)	1·13×1·17	23·62"=600 mm	1155	·29=7·4	2504	Slight defect
4017		1·14×1·17	"	1220	·33=8·4	2600	Sound
4018		1·10×1·16	"	1170	·31=7·9	2648	do.
4019		1·11×1·19	"	1240	·32=8·1	2644	do.
			Mean	1196	·31=7·9	2599	
4020	$1^1/_4$" dia. Bars 15" parallel American standard (Cast vertically)	1·23×1·29	12 ins.	3020	·11	2500	Slight defect
4021		1·22×1·25	"	3305	·12	2936	Sound
4022		1·20×1·28	"	3230	·11	2796	do.
4023		1·23×1·26	"	3150	·10	2744	do.
			Mean	3176	·11	2744	

In the round Bars the indicated joint of mould was placed in neutral position in each case. When calculating the results of the round bars to obtain their equivalent upon Bars 1"×2" (B D) (English section) the rounds have been considered with regard to section as equal to ·7854 of the B D². For example, Test No. TT 4016 1·13×1·17 (B D²); 1·54×·7854=1·21 (B D²) the relative figure taken for the calculations. Unfortunately the founders cast the English Bars (1"×2") on flat instead of on edge.

J. E. STEAD Esq. F. R. S.
11, Queens Terrace, Middlesbrough.

DAVID KIRKALDY and SON.
99, Southwark Street, London S. E.
27th Sept. 1911.

English was 696 lbs., in the German 48 lbs. and in the American bars was 192 lbs. The maximum difference in deflection in the English was .04" in the German .02" and in the American bars was .02".

Table II.

Results of Experiments to ascertain the Tensile Strength etc. of specimens prepared from the Bars after testing under Bending.

Test. No.	Description		Dimensions		Ultimate Stress			Appearance of Fracture
			Dia.	Area	Total	Per square inch.		
TT			inch.	sq. ins.	lbs.	lbs.	tons	
		From Bar	turned					
4384	From	TT 4012	·792	·493	12 260	24·868	= 11·1	Sound
4385	2"×1" Bars	„ 4013	·796	·498	12·160	24·418	= 10·9	do.
4386	English	„ 4014	·787	·486	12·340	25·391	= 11·3	do.
4387	Standard	„ 4015	·791	·491	12·400	25·255	= 11·3	do.
					Mean	24 983	= 11 2	
4388	From	„ 4016	·798	·500	13·240	26·480	= 11·8	Sound
4389	$1^3/_{16}$" Bars	„ 4017	·798	·500	13·620	27·240	= 12·2	do.
4390	(German	„ 4018	·798	·500	13·860	27·720	= 12·4	do.
4391	standard)	„ 4019	·798	·500	14 000	28·000	= 12·5	do.
					Mean	27·360	= 12·2	
4392	From	„ 4020	·798	·500	13·940	27·880	= 12·4	Sound
4393	$1^1/_4$" Bars	„ 4021	·798	·500	13·920	27·840	= 12·4	do.
4394	(American	„ 4022	·797	·499	13 390	26·834	= 12·0	do.
4395	standard)	„ 4023	·798	·500	13·300	26·600	= 11·9	do.
					Mean	27·288	= 12·2	

In the round Bars the indicated joint of mould was placed in neutral position in each case. When calculating the results of the round bars to obtain their equivalent upon Bars 1"×2" (B D) (English section) the rounds have been considered with regard to section as equal to ·7854 of the B D². For example, Test No. TT 4016 $1·13 \times 1·17$ (B D²)

B D²

$1·54 \times ·7854 = 1·21$ the relative figure taken for the calculations. Unfortunately the founders cast the English Bars (1"×2") on flat instead of on edge.

J. E. STEAD Esq. F. R. S.
11, Queens Terrac, Middlesbrough.

DAVID KIRKALDY and SON.
99, Southwark Street, London S. E.
27th Sept. 1911.

In the case of the bars for tensile strength the maximum difference in ultimate stress on the English bars was .4 ton in the German bars .7 ton and in the American bars .5 ton.

The mean results obtained on the English bars is exactly one ton less than the German and American bars, the results of

the two latter being identical. Unfortunately by an oversight of the moulder the English bars were cast on the flat instead of on the edge as is the usual practice; in the case of bars cast on the flat any little unsoundness such as a blow-hole appreciably affects the transverse strength of the bar when tested on edge and for this reason and also to obtain the results from bars of an entirely different mixture cast under different conditions Mr. Kirkaldy arranged with Messrs. Young & Co. London to cast another series of bars under his supervision, and these were duly cast in his presence. Full details of the results obtained are given in Tables III & IV and the analyses made by Dr. Stead and Mr. Harbord independently are also attached. In these sets six of each of the standard bars were cast, four of each on one day from the same ladle and the remaining two oı each on another day. In the Transverse tests the maximum difference in ultimate Stress taken on the sound bars in the case of the English test bars was 472 lbs, and the maximum difference in deflection was .05". In the case of the German bars calculated to the equivalent load upon the English standard bar the maximum difference in ultimate Stress was 464 lbs. and the maximum difference in deflection was .09" and on the American bars the results were respectively 456 lbs. and .03" deflection. The smaller difference in deflection in both of the American sets of bars was to be expected, owing to the shorter length of the test bars and consequently much smaller total deflection obtained.

The results of the experiments on the tensile strength, eliminating the unsound bars, shows, in the English, a difference of .4 tons, in the German 1.3 tons and in the American, bars .8 tons. The average of all the bars shows that the English test bar gives a slightly lower result than the German and American, the two latter being almost identical, but if the unsound bars in the English series be omitted the average of these is slightly higher than either the American or the German. It should be noted that in this series the English tensile tests were made without removing the skin as has been the practice for many years, whereas in the case of the German and American it was necessary to remove the skin to obtain a suitable specimen apart from fulfilling conditions laid down in the Specification. Broadly looking at the results obtained the shape of the bar seems to have little effect on the physical

Table III.

Results of Experiments to ascertain the Transverse Strength etc. of Iron Bars cast at the Foundry of Messrs. H. Young and Co. Ld., Nine Elms, London, S. E.

Test No.	Description	Dimensions	Span.	Ultimate Stress	Ultimate Deflection	Calculated Equivalent load upon English Standard Bar 1"×2" 36" span.	Appearance of Fracture
TT		inches	inches	lbs.	inch. mm	lbs.	
		B D					
5453	A	1·03×2·06	36	3480	·42	3184	Sound
5455	English A	1·03×2·03	36	2770	·34	2612	Skin defect (bottom edge)
5457	Standard B	1·02×2·05	36	3420	·42	3188	Sound
5459	1"×2" B 3' 4" long.	1·01×2·04	36	3020	·38	2876	do.
5461	cast on edge. C	1·03×2·06	36	3660	·43	3348	do.
5463	C	1·02×2·03	36	3290	·40	3132	do.
			Mean	3273	·40	3057	
		B D					
5464	A	1·23×1·24	23·62" = 600 mm	1800	·41 = 10·4	3192	Sound
5466	German A	1·21×1·22	"	1630	·35 = 8·9	3032	do.
5468	Standard B	1·20×1·25	"	1590	·32 = 8·1	2840	do.
5470	$1^3/_{16}$" dia B	1·22×1·28	"	1860	·38 = 9·6	3108	do.
5472	$25^1/_2$" long. C	1·23×1·21	"	1540	·34 = 8·6	2864	do.
5474	C	1·25×1·23	"	1540	·35 = 8·9	2728	do.
			Mean	1660	·36 = 9·1	2961	
		B D					
5476	A	1·23×1·27	12 ins	3050	·12	2624	Sound
5478	American A	1·23×1·25	"	3360	·15	2968	do.
5480	Standard B	1·23×1·25	"	3490	·12	3080	do.
5482	$1^1/_4$" to $1^3/_{16}$" dia B	1·26×1 28	"	3690	·14	3036	do.
5484	15" long. C	1·25×1·26	"	3280	·15	2804	do.
5486	C	1·24×1·26	"	3430	·13	2952	do.
			Mean	3383	·135	2910	

In the round Bars the indicated joint of mould was placed in neutral position in each case. In calculating the results of the round bars to obtain their equivalent upon Bars 1"×2" (English section) the rounds have been considered with regard to section as equal to ·7854 of the B D². The bars marked A and C were cast on the same day from the same ladle. Those marked B were cast on another occasion, all the moulds not being quite ready for pouring same time as originally intended.

All the bars were cast in the presence of our Mr. William G. Kirkaldy.

F. W. HARBORD Esq. F. I. C.
16, Victoria Street, Westminster S. W.

DAVID KIRKALDY and SON.
99, Southwark Street, London S. E.
21st Dec. 1911.

Table IV.

Results of Experiments to ascertain the Tensile Strength etc. of Iron Bars cast at the Foundry of Messrs. H. Young and Co. Ld., Nine Elms, London, S. E.

Test No.	Description		Dimensions Dia.	Dimensions Area	Ultimate Stress Total	Ultimate Stress Per square inch.	Appearance of Fracture
TT			inch.	sq. ins.	lbs.	lbs. tons	
5452		A	1·25	1·227	38·490	31·369 = 14·0	Sound
5454	English	A	1·25	1·227	38·400	31·296 = 14·0	do.
5456	Standard	B	1·28	1·287	31 590	24·545 = 11·0	Slightly unsound
5458	Tensile Bar	B	1·25	1·227	37·320	30·415 = 13·6	Sound
5460	Tested with skin on	C	1·26	1·247	38·700	31·034 = 13·9	do.
5462		C	1·27	1·267	33·720	26·614 = 11·9	Slightly unsound
					Mean	29·212 = 13·0	
			turned				
5465		A	·798	·500	15·420	30·840 = 13·8	Sound
5467	German	A	·798	·500	15·080	30·160 = 13·5	do.
5469	Standard	B	·798	·500	14·040	28·080 = 12·5	do.
5471	Specimens prepared	B	·798	·500	14·480	28·960 = 12·9	do.
5473	From Bars after testing	C	·798	·500	15·540	31·080 = 13·9	do.
5475	Under Bending	C	·798	·500	15·260	30·520 = 13·6	do.
					Mean	29.940 = 13·4	
			turned				
5477		A	·798	·500	15·500	31·000 = 13·8	Sound
5479	American	A	·798	·500	15·340	30·680 = 13·7	do.
5481	Standard	B	·798	·500	14·600	29·200 = 13·0	do.
5483	Specimens prepared	B	·798	·500	15·180	30·360 = 13·6	do.
5485	From Bars after testing	C	·798	·500	15·200	30·400 = 13·6	do.
5487	Under Bending	C	·798	·500	14·780	29·560 = 13·2	do.
					Mean	30·200 = 13·5	

In the round Bars the indicated joint of mould was placed in neutral position in each case. In calculating the results of the round bars to obtain their equivalent upon Bars 1″ × 2″ (B D) (English section) the rounds have been considered with regard to section as equal to ·7854 of the B D^2. The bars marked A and C were cast on the same day from the same ladle. Those marked B were cast on another occasion, all the moulds not being quite ready for pouring same time as originally intended.

All the bars were cast in the presence of our Mr. William G. Kirkaldy.

F. W. HARBORD Esq. F. I. C.
16, Victoria Street, Westminster S. W.

DAVID KIRKALDY and SON.
99, Southwark Street, London S. E.
21st Dec. 1911.

4

Analyses of Iron Bars cast at the Foundry of Messrs. Young and Co. Ld.

Analyses by Edwd. Riley and Harbord.

Lab. No.	Marks	Total Carbon	Graphitic Carbon	Combined Carbon	Sulphur	Silicon	Phosphorus	Manganese	Arsenic	Copper
8515	A	3·480	2·700	0·780	0·099	1·405	1·165	0·418		
8518	A	3·406	2·675	0·731	0·096	1·429	1·139	0·416		
8521	A	3·428	2·790	0·738	0·095	1·443	1·110	0·403	0·014	
8516	B	3·450	2·670	0·780	0·098	1·557	1·161	0·422		
8519	B	3·519	2·844	0·622	0·101	1·606	1·047	0·414		
8522	B	3·387	2·684	0·703	0·110	1·617	1·098	0·422	0·011	
8517	C	3·459	2·671	0·795	0·094	1·485	1·144	0·414		
8520	C	3·456	2·684	0·771	0·101	1·433	1·101	0·403		
8523	C	3·466	2·686	0·780	0·098	1·462	1·156	0·406	0·012	
Average		3·450	2·711	0·745	0·099	1·493	1·123	0·413	0·012	0·053

Average Analyses of Iron Bars made by Messrs. H. Young and Co. Ld. London.

Analysis made by	Total Carbon	Graphitic Carbon	Combined Carbon	Sulphur	Silicon	Phosphorus	Manganese	Arsenic	Copper
Edwd. Riley and Harbord	3·450	2·711	0·745	0·099	1·493	1·123	0·413	0·012	0·053
Pattinson and Stead .	3·400	2·695	0·705	0·108	1·400	1·117	0·403	0·012	0·047

Average Analyses of Iron Bars made by Messrs. Richardsons, Westgarth and Co. Ld. Middlesbrough.

Analysis made by	Total Carbon	Graphitic Carbon	Combined Carbon	Sulphur	Silicon	Phosphorus	Manganese	Arsenic	Copper
Edwd. Riley and Harbord	3·191	2·476	0·715	0·132	1·562	1·233	0·432	0·026	0·024
Pattinson and Stead .	3·160	2·510	0·650	0·128	1·568	1·222	0·431	0·032	0·024

properties provided the bars are sound, but it would appear that there is a little more difficulty in insuring sound bars cast to the English section than in the case of either the American or the

German bars. In view of the small differences obtained with the bars of different shapes your Committee do not feel that the results call for any recommendation except that they do consider it desirable that any bar for testing for deflection by transverse stress should not be less than 24 inches long, as with shorter bars than this it is very difficult to measure to the required degree of accuracy except with very delicate measuring instruments, and any slight error which would be liable to occur under ordinary works conditions of testing would be greatly magnified by using a shorter bar than this.

The thanks of the Association are especially due to Messrs. Richardsons, Westgarth & Co. of Middlesbrough and Messrs. Young & Co. of London who not only cast the bars without any charge but took a personal interest in seeing that every precaution was taken to ensure sound castings and that all the bars should be cast under identical conditions.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

APPLICATION OF THE METHODS OF MECHANICAL TESTING ADOPTED FOR OTHER METALS TO FOUNDRY PIG TESTING.

By **A. Damour**, Maître de Forges Bayard.
(Translated from the French by H. Borns.)

Before starting on an examination of the diverse tests to which pig iron is usually submitted, and before investigating if there be any reason for pursuing in a unification of the methods to be applied, it appeared to us indispensable to elucidate two essential facts which had very justly been emphasiced at the last Congress of Copenhagen by Messrs Greiner and Moldenke.

1. The chemical analysis, no more than mechanical tests of specimens, can not furnish any information as to the real intimate qualities of foundry pig We must not expect from the analysis more than indications as to the nature of the metal which has been utilised for the preparation of the specimens in question.

2. There is no pig which one can briefly qualify "as good or bad". There is no pig which is "pure or impure". The qualifications, "good or bad", applied to pig do not correspond to any objective reality, because every kind of pig is good for some purpose and bad for another. In the same way the expression "impurities" applied to certain constituents of pig falsifies the ideas of most users of pig. Pig is nothing else but the metal, produced in the blast furnace by treating different iron ores with some fuel and some flux, and the varied chemical elements which are found in the final product form the ensemble of the constituents and not of impurities.

This granted, what interest can the consumer of foundry pig take in tests of specimens such as he demands from the suppliers? The almost unique point of interest in our opinion is to enable him to assure himself, that the metal as furnished falls well within the category of the primary materials which experience has shown to be suitable for the intended purpose. It would be imprudent to deduce from the success of the tests which had been demanded that one has to deal with wares which must surely give every satisfaction in service.

Practice shows indeed that any particular piece will give satisfaction, when we make use of a foundry pig of a certain nature; but after having assured ourselves that the article is well cast from the materials agreed upon, it is indispensable to have recourse to direct experiments submitting the casting to stress analagous to those which it will have to undergo in service, if we wish to acquire any certainty that we shall be fully satisfied with the material furnished.

If we admit all that has been said, it appears to us to be legitimate to conclude, that the diverse mechanical tests applied to cast iron should have above all the object to bring out the possible variations in the quality of a pig of a certain nature. It is not necessary for this purpose to apply to the pig the whole ensemble of the mechanical tests, now-a-days so multiple, which permit to reveal the intimate properties of the other metals.

It is on the contrary indispensable precisely to fix the conditions in which the experimenters ought to place themselves so that that they may be able always to work under identical conditions.

Up to the present nothing has been achieved in this direction, and the strength values, claimed for different kinds of pig which are brought on the market, have very little interest and value, because we do not know whether they be intercomparable with one another.

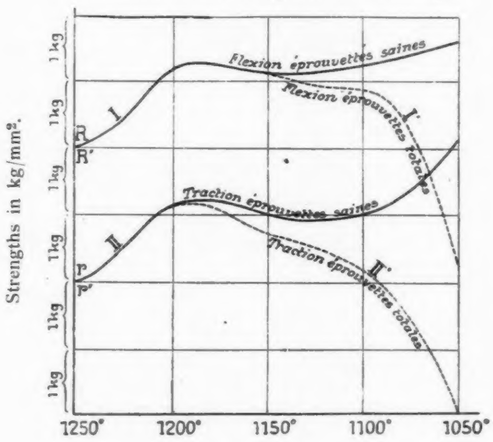
Although it has often been demonstrated that testing the same material will bring out strong discrepancies, we de not consider it useless to point this fact out once more. Our experiments have been made with foundry pig from Lorraine, and we have conducted a great number of experiments of which we are going to give a résumé lower down.

We have always worked with refused material, and we have confined ourselves to traction and bending tests, because there was no time to undertake other tests, and because we considered those tests as the most characteristic.

A. Influence of the temperature of Casting.

We have operated between the limits of temperature 1260 and 1030° C and taken the temperature in the ladle at the moment of casting. The observed discrepancies in the strengths can be

Influence of the Temperature of Casting.



Temperature of pig at moment of casting.

Fig. 1.

I = bending of sound specimens.
I' = bending of all the specimens.
II = traction of sound specimens.
II' = traction of all the specimens.

seen in the curves. Our specimens were cylindrical, of a diameter of 25 mm, and they have been examined without turning, rough as they come from the foundries. If we designate by r kg the strength per square mm corresponding to the rupture stress in traction of sound specimens cast at 1250°, and by r' that of all the specimens, further by R and R' the rupture strengths in bending

tests (the distance between the supports being equal to 20 diameters) of specimens also cast at this same temperature, we have successively obtained the following results.

Influence of the Temperature of stripping the specimens.

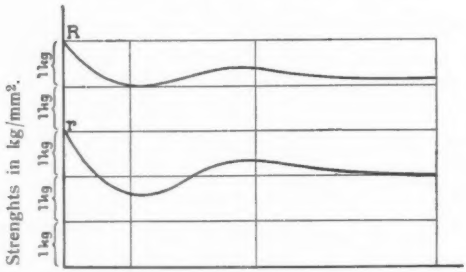


Fig 2.

	sound specimens	all the specimens
cast at 1250° broken in tension at	r' kg	r kg
„ „ 1190° „ „ „ „	r' + 1·1	r + 1·1
„ „ 1150° „ „ „ „	r' + 0·7	r + 1·0
„ „ 1100° „ „ „ „	r' + 0·1	r + 1·0
„ „ 1060° „ „ „ „	r' — 2·0	r + 2·0
bending tests:		
cast at 1250° broken at	R'	R·
„ „ 1190° „ „	R' + 1·2	R + 1·2
„ „ 1150° „ „	R' + 1·1	R + 1·1
„ „ 1100° „ „	R' + 0·9	R + 1·3
„ „ 1060° „ „	R' — 1·8	R + 1·6

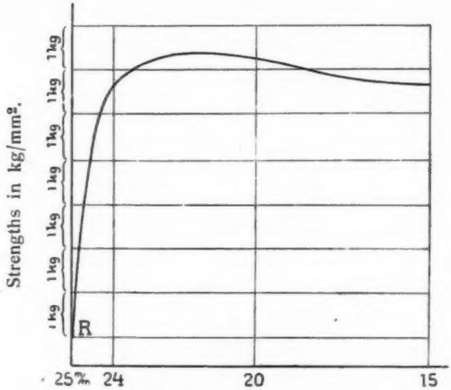
B. Influence of the Temperature of Stripping the specimens.

The temperature at which we took the specimens out of the mould had a noteworthy influence upon their strength, as the curves demonstrate.

We found successively:

breaking strength in tension r for stripping at bright cherry red
„ „ „ „ r — 1·4 for stripping at dark „ „
„ „ „ „ r — 0·7 „ „ „ dull red
„ „ „ „ r — 1·0 „ „ „ in the cold.

Influence of turning the specimen.
Bending tests.



Diameters of the specimens.

Fig. 3.

In bending tests; breaking strength:

R	for	specimens	stripped	at	bright cherry red
R — 1·0	„	„	„	„	dark „ „
R — 0·6	„	„	„	„	dull red
R — 0·7	„	„	„	„	first red glow
R — 0·8	„	„	„	„	in the cold.

C. Influence of Turning the specimens.

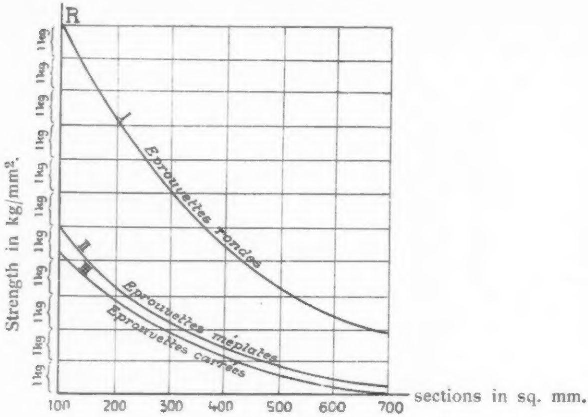
We started with cylindrical specimens 25 mm in diameter which we turned down successively to $D_2=24$, $D_3=20$, $D_4=15$, with the following results:

	D=25	D=24	D=20	D=15
Bending strength	R	R+5·7,	R+6·2,	R+5 7.

D. Influence of the degree of Polishing the Specimens.

When we operate on turned specimens, the grooves left by the cutting tool have a notable and always injurious influence on the strength, and when we polish the specimen carefully with emery paper, so as to obtain a perfectly smooth surface, we arrive at considerably modified test results.

Influences of the area and of the shape of the cross sections of the specimens.



Bending tests of specimens cast at uniform temperature, in stove-dried sand, taken cold out of the mould.

Fig. 4.

I = round specimens.
II = half-flat specimens.
III = square specimens.

E. Influence of the area of the cross-Section of the Specimens.

The experiments show that for the same form of cross-section of the specimen the mechanical resistance varies notably with area. Several hundreds of bending tests have given the results which are plotted in the curves on the next page. We see there in the case of round specimens for instance, cast in sand, air-dried at a uniform temperature, taken out of the mould cold, and not turned. that the resistance to bending varies from R. corresponding to a diameter of 11 mm, to R—9for the diameter of 30 mm. In the traction tests we obtain analogous, though more sinuous curves.

F. Influence of the Shape of the cross-Section of the Specimen.

For the same area of cross-section the results of mechanical tests vary considerably with the shape of the specimens. The

curves given bring this peculiarity out very well. We notice, for instance, that for the particular section of 300 sq. mm the bending strength is equal to R in the case of a circular section; it becomes equal to R—3·8 for a half-flat section (1 by 2·1), and to R—4·0 for the square section. The traction tests give analogous results.

G. Influence of the Orientation of the Mould when Casting

We have been investigating the influence of the orientation of the mould at the moment of casting and we have found slight differences in favour of specimens cast standing. In bending tests these latter have given, for cylindrical specimens of 25 mm, bottom-cast in dried sand moulds, an increase in the strength equal to 3·0 kg per mm^2, by reference to specimens which were cast flat, the dirty surface being below.

The examination of all the variations pointed out in our remarks seems clearly to impose upon us the necessity for laying down the precise conditions under which cast specimens should be prepared for the future. In the absence of any precise regulations it is impossible to derive any advantage from tests claimed for such and such a kind of pig, and to make a choice between a series of offered products without having recourse to personal tests.

We are, therefore, of the opinion that before attempting any other research on foundry pig it is indispensable to agree upon some method of operation for preparing characteristic specimens. We consider, that we should have a good chance of placing ourselves in the most favourable conditions if we proceed uniformly in the following manner:

1. Cast the specimens from a pig brought up to the temperature of 1100 or 1200° C.

2. Cast the specimens in moulds of hot sand placed vertically.

3. Take the specimens out of the completely cooled mould after a minimum of two hours of rest.

4. Conduct the tests uniformly on cylindrical specimens, 25 mm in diameter, rough as they come from the foundry. By proceding as indicated above the same kind of pig will have a good chance of giving sensibly constant results when submitted to tests. It will then be possible to draw up, for each kind of pig, tables of figures that are really intercomparable.

The Congress will certainly be of the opinion that the pursuit of this aim offers the greatest interest, and that we might look forward to its realisation, if we could agree upon what I should propose to call a "specimen of international type".

Résumé of the Note by M. Damour.

The mechanical tests of specimens of foundry pig can not do more than bring out the possible variations in the quality of the product and furnish a control that a good casting has been obtained from the pig which had been selected.

For this purpose it will be necessary to conduct the tests under identical conditions so as to render them comparable. For the results will vary in wide limits according to the method by which we proceed. Nothing has so far been done to fix a mode of operation for the experimenters, and the first task of the Congress should in our opionion be to establish this mode of operation in order to arrive at a precise definition of the specimen of international type.

Proposals for fixing this specimen.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

NOTE ON THE WEAR OF BRONZES.

By **A. Portevin** and **E. Nusbaumer.**
Usines de Dion-Bouton, Paris. Usines G. Derihon, Liége (Belgium) and Jeumont (France).

(Translated from the French by. H. Borns.)

The researches described in this Note have been undertaken for the purpose of determining the influence of the chemical composition on the wear of bronzes.

I.

Table 1 gives the chemical composition and the hardness of the bronzes which have been examined. The constituent metals, electrolytic copper and commercially pure tin, were melted in crucibles of plumbago of a capacity of 50 kg. Figure 1 shows the

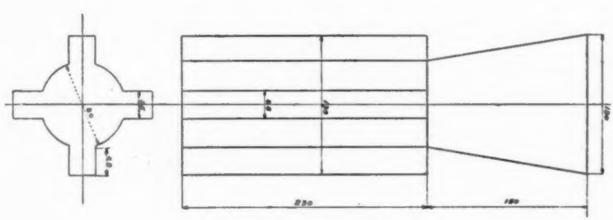


Fig. 1.

model of the castings which were made in sand. The longitudinal projections were cut off with the saw, and we thus obtained four bars of 25 by 25 by 230 mm per ingot from which everything was taken that was required for the tests. None of the specimens were subjected to any thermal treatment whatever.

II.

The apparatus employed for these researches is the mill of Derihon. We shall not describe this apparatus again, since a description has appeared in a Note which, al hough not official, was presented to all the members of I. A., present at the Copenhagen Congress in 1909. We can only mention that the principle of the apparatus is based upon the determination of the friction between a specimen and the circumference of a polished wheel which turns at high speed in an oil bath. A lever bears against the specimen with the pressure of a known weight, and as this lever descends in accordance with the wear of the specimen, the latter factor can be determined with the aid of a micrometer screw.*)

III.

The results which are specified below have been obtained under the following experimental conditions.

The speed of the wheel of the machine was always 3200 revs. per minute. Each test was continued for two million turns, that is to say, until 2000 km had been developed.

The oil which was used for lubrication was the oil commercially known under the name of Autol clear quality, such as is used in lubricating the high-speed gear boxes of automobiles. The tests to which this oil was several times submitted, in order to make sure of its constancy during the course of our researches, have shown a satisfactory concordance, and they have given the following mean results:

Density at 15°	0·912
Viscosity Engler at 15°	54·6
Viscosity Engler at 50°	6·15
Flash point in a closed vessel	209°
Flash point in air.	246°

The lubrication was controlled by making use of the variations of the amperemeter which was traversed by the current actuating the dynamometer; the current in this amperemeter was influenced by the volume of the oil charged into the apparatus. When the oil basin was empty, the amperemeter indicated generally 3·5 or

*) F. E. Nusbaumer, Note sur l'Usure des Métaux. V. Congress Internat. Assoc. for Testing Materials, Copenhagen 1909.

4 amperes at 220 volts. The oil feed was regulated in such a way that the amperemeter showed a minimum of current intensity without letting the specimen squeak. This result was obtained for each of the 8 bronzes examined by employing a total volume of oil of 2 l. In consequence of the inevitable losses and escapes this volume varied slightly in the long run. Yet the variation

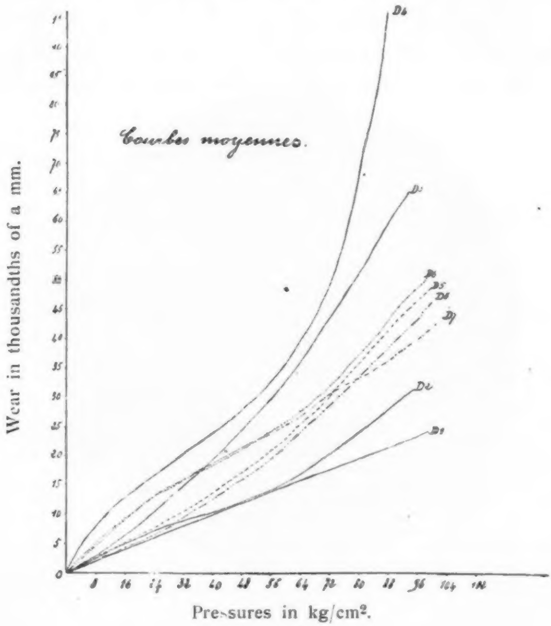


Fig. 2.

Courbes moyennes = Curves of means.

never exceeded 100 cm³ per week, and it was easy to allow for this definency by adding a sufficient quantity of oil to supplement the volume again to two litres. The oil was emptied about every two months, and every six months the machine was taken to pieces and cleaned to remove dust and mud which projected by the centrifugal forces which had collected in the interior of the box.

The flow of the water, which was used to maintain the apparatus at a sensibly constant temperatur, was regulated in such

a way that there was a difference of from 2·5 to 3⁰ between the temperatures at entrance and at exit.

The curves of No. 2 show the results of our tests. The wear of the specimens is expressed as a function of the pressure per cm^2 which these specimens suffered. It will easily be seen that these curves may be divided into three groups as shown in the diagram: 1st the curves D 1, D 2; secondly, the curves D 5, D 6, D 7, D 8; thirdly, the curves D 3, D 4. In the bronzes which o not contain any phosphorus an increased in the tin percentage

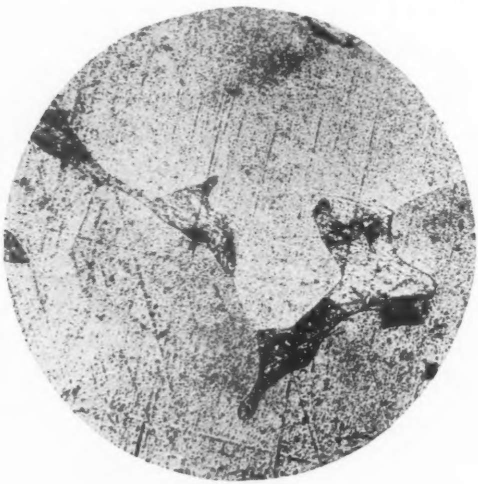


Fig. 3.

tends to raise the wear. This increase is only slightly noticeable as long as the proportion of tin does not exceed 10 per cent. But above this contents the wear becomes relatively considerable, and the influence the tin is particularly injurious in cases where a strong pressure is applied (bronze D 4).

The introduction of phosphorus into the bronzes produces a rather curious effect. Whilst the phosphorous bronzes of low tin contents (Sn inferior to 10 %) wear rather more than the non-phosphorous bronzes otherwise of the same composition, bronzes of more than 10 % of tin wich further contain phosphorus are decidedly less subject to abrasion than the corresponding non-

phosphorous bronzes. The introduction of phosphorus produces therefore an average bronze in which relatively considerable variations in the tin percentage are not accompanied by more than rather feeble variations in the corresponding wear. Yet the wear remains proportionate to the contents of tin, or more exactly to the quantity of the δ constituent present.

It was interesting to ascertain what would be the wear of a bronze from which the δ constituent had disappeared. We have chosen for this experiment the bronze D 7, from which we eliminated the δ constituent by water-hardening at 700° (Fig. 3).

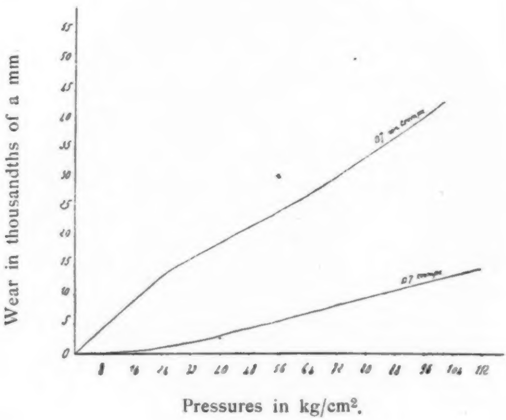


Fig. 4.

Figure 4 shows the curve of the wear of D 7 after this treatment. The curve keeps decidedly below that of D 1, and the elimination of δ well marks the minimum wear of the bronzes which have been studied.

Every point 8, 16, 24, etc of the different curves of Fig. 2 has been made the object of at least three tests. We must, however, add that the results of these experiments have not always been absolutely concordant. The curves of Fig. 2 have been traced from the means obtained in the different tests. Figs 5 and 6, on the other hand, reproduce the curves which have been obtained by marking in the one case (Fig. 5) only the values of maximum wear, and in the other case (Fig. 6) the values of minimum wear, such as we have found for corresponding pressures in bronzes

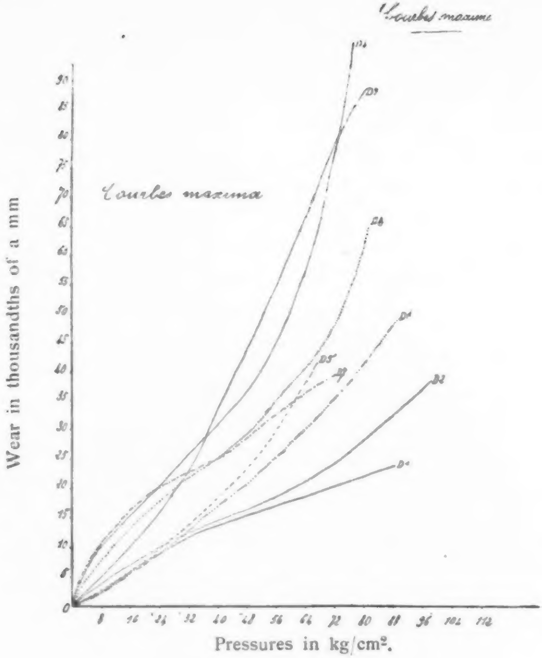


Fig. 5.
Courbes maxima = Maximum curves.

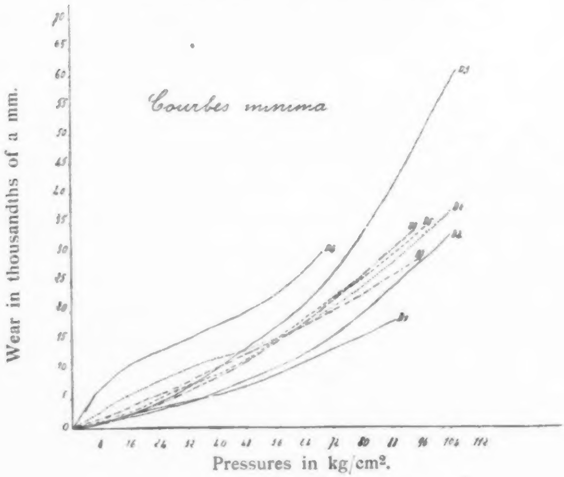


Fig. 6.
Courbes minima = Minimum curves.

which have not been hardened. We will call the curves of Fig. 5 maximum curves and those of Fig. 6 minimum curves. We shall easily recognise that the curves of Fig. 2 and 5 have the same general trend and that they differ only by some units in their absolute values. As we could, especially in experiments of this kind, not guarantee values within a few thousands of a mm, it will be admitted that the two diagrams are sufficiently concordant. In the minimum curves the deviations are, on the other hand,

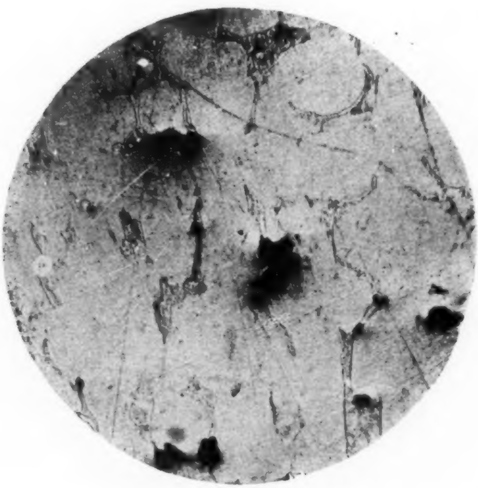


Fig. 7

very small; there might result, with regard to Fig. 2, slight differences in the comparative trends of the curves D 1, D 2, etc.

Some discrepancies revealed by a consideration of the total results would have been more serious. We have found a few of this kind in the course of this research. Some of them, perhaps 3 or 4 in all, we have, after looking for a long time in vain for an explanation, been obliged, for want of any better reason, to attribute to local accidents, inopportune overheating, disturbance of the machine by some exterior cause (shock tests made on the same piece etc.) The others (about a dozen) have on the contrary

put us in the way of recognising a rather interesting phenomenon of which we will now speak.

In the case of certain of our bronzes the wear, ofter having first been normal, suddenly diminished strikingly, dropping almost to zero at a very rapid rate. The experiment was then continued a little further than usually, and after the wheel had thus been made to describe three or four million turns, the specimen suddenly would give way, wearing off in less than 1 second by 1 mm (**1000/1000** ths), without our being able to foresee in any way the

Fig. 8.

moment and the cause of the breakdown. It was not a question of a seizure caused by a want of oil. For the specimen when immediately withdrawn, did not show any indication of burning, neither to the eye, nor to the touch. It was simply a question of a sudden and large wear following a period of no wear.

The micrographical examination of the test specimens, on which this phenomenon had been observed, did not at first reveal anything to us (experiment 1, fig. 7). But it occurred to us to anneal our specimen for 30 mins. at **600⁰** and to examine it subsequently. We then observed a coarse, decidedly crystalline and

mottled texture (experiment 2, fig. 8). A third polishing followed by etching gave revealed, on the contrary, a normal texture from which the crystals and the specks had noticeably disappeared (experiment 3, fig. 9).

It was therefore evident that we had, in the case of experiment 1, been dealing with a cold-worked metal which was capable of recrystallising when annealed (experiment 2).

In order to confirm this hypothesis we took a piece of bronze D 7, of 25 by 25 by 40 mm, in which the phenomena of

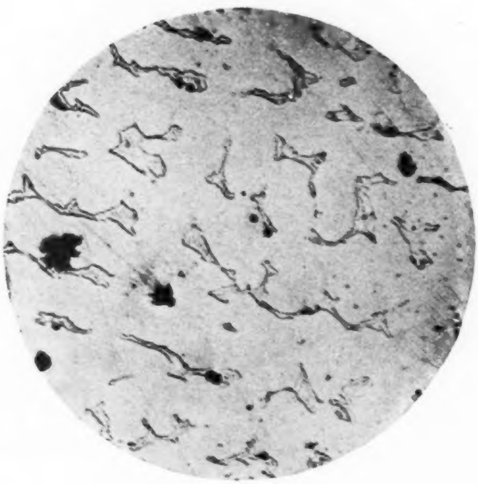


Fig. 9 and 10.

the absence of wear followed by a breakdown had been particularly striking. This piece was cut in two. The one half was compressed under the hammer on an anvil so as to reduce the tickness from 20 to about 12 mm. The other half was left intact. The two portions, hammered and not hammered, did not under the microscope reveal anything of particular interest. They were then annealed at 600° C. for 30 mins. in a salt-bath furnace, taking care to prevent any oxidation of the specimen. After this treatment the specimen which had not been hammered displayed the same structure as before (Fig. 10). The specimen which had

been hammered, on the other hand, showed numerous mottled polyhedra similar to those which the surface layer of D 7 had shown after annealing (Fig. 11). We should add that the period of non-wear in a specimen often corresponded to an increase in the hardness figure. Thus a specimen of D 1, after a period of non-wear, gave a rebound of 35 on the Shore sclerescope instead of 21, which would be the normal value for this bronze.

Fig. 11.

Our hypothesis was therefore quite exact. The phenomena of non-wear corresponded to a state of superficial cold-work of the specimen. The worked surface-skin disappeared as soon as the limit to which the cold-work had penetrated had been reached, and this disappearance corresponded to a rapid wear and to a real breakdown of the specimen.

Summing up we can say that under the special conditions which were adopted:

1. The wear of the ordinary bronzes is proportional to the tin percentage or more exactly to the percentage of δ.

2. The introduction of phosphorus has the effect of producing a bronze which wears less than a non-phosphorous bronze of high

tin percentage, and more than a non-phosphorous bronze of low tin percentage.

3. When a bronze is bearing against a polished steel journal, even under abundant lubrication, there may be produced a skin of cold-worked bronze at the surface, which skin does not suffer more than very little wear. When the limit of this film or skin has been reached, the wear becomes extremely rapid in the case of the examined bronze.

4. The tendency to crystallise on annealing which favours the effect of cold-work is found in bronzes as well as in the steels and seems to be a phenomenon of extremely general character.

Table 1.

Mark	Cu	Sn	P	Pb	Fe	Zn
D 1	91·12	5·73	0	0·12	0·15	2·68
D 2	88·31	8·78	0	trace	0·31	2·40
D 3	84·45	13·89	0	0·23	0·04	1·22
D 4	80·22	19·16	0	trace	0·13	0·43
D 5	94·80	5·08	0 011	0	0	0
D 6	89·54	10·02	0·012	0	0·05	0·21
D 7	85·45	14·42	0·015	0	0·05	trace
D 8	80·11	19·79	0·020	0	0·08	trace

Ball-Hardness.

Pressure: 1000 kg; diameter of ball: 10 mm. The diameters of the impressions are means of 6 tests.

Mark	Diameter of impression	Extreme deviations	Mark	Diameter of impression	Extreme deviation
D 1	43·25	± 1·75	D 5	41	± 1
D 2	39	± 1	D 6	39	± 1
D 3	36·5	± 1·5	D 7	34·5	± 0·5
D 4	29·20	± 0,75	D 8	29	± 0·5

Hardness by the Shore Scleroscope:

Pellet of hardened steel, weight 2·3 g.

Mark	rebound	Mark	rebound
D 1	21 25	D 5	22·75
D 2	26	D 6	27·50
D 3	32	D 7	37·25
D 4	50	D 8	57·75

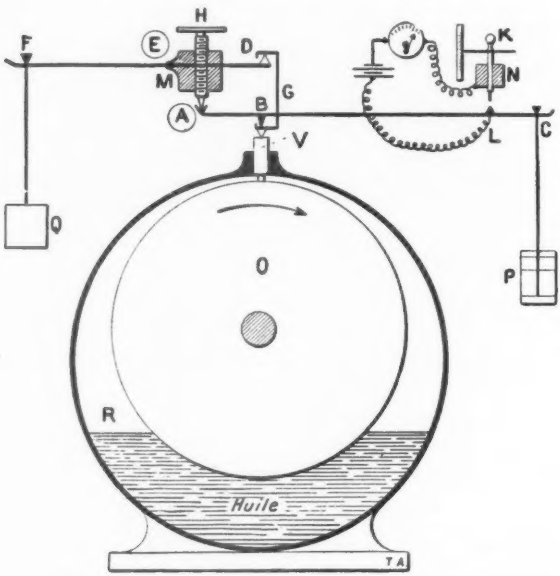


Diagram of Derihon's abrasion mill (wear gauge).

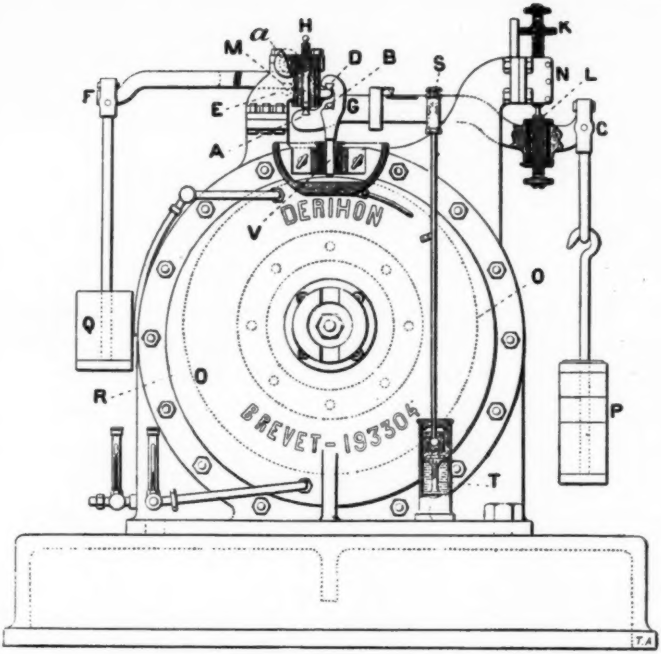
A, B, C, knife-edges of the lever carrying the weights P.

D, E, F, knife-edges of the compensating balance beam. The latter ends in a fork the branches of which pass in front and behind the support of the adjusting-screw H. This screw has a square end and it is raised and lowered by turning a screw-nut held in the support M through the agency of a button *a* and a tangent screw.

G Yoke receiving the knife-edges B & D and passing on the sample V

K. micrometer-screw. — L. stop-screw insulated by an ebonite sleeve and connected to one terminal of a battery into the circuit of which is inserted a galvanometer. — N. support of the screw K.

O, friction disk. — Q, Balance weight. — R, oil-reservoir.



(Same letters as in figure on page 12.)

S swivels arranged on opposite sides of the balance-beam A, B, C, and connected by means of rods to the dampers T.

Summary.

The authors have studied the wear of bronzes rubbing against polished steel with abundant lubrication. They have arrived at the following conclusions;

1. The wear of the ordinary bronzes in proportional to the contents of δ.

2. The introduction of phosphorus has the effect of creating a bronze which wears less than non-phosphorous bronzes of high tin percentage, and more than non-phosphorous bronzes of low tin percentage.

3. When the bronzes are submitted to constant friction, account should be taken of the phenomena of cold-work, which tends to diminish the wear until the limit of the depth to which the cold-work has penetrated is reached.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

METHOD FOR THE RAPID DETERMINATION OF TOTAL CARBON IN IRON, STEEL, CAST-IRON AND IN THE IRON ALLOYS.

By Mr. H. de **Nolly**,

of the Compagnie des Forges et Aciéries de la Marine et d'Homécour, St. Chamond.

(Translated by G. Lemmy, London.)

Object of the Method.

The object aimed at was to arrive at a sufficiently accurate method for determining the proportion of carbon, which might replace those now followed in the Laboratories, and be at the same time sufficiently rapid to allow the following up of a heat, in the Siemens-Martin or in the electric furnace. The method, described below, has all the advantages of the dry method and, from the point of view of rapidity, is superior to the Eggertz colorimetric process.

Principle.

The method consists in burning the metal in a limited volume of pure oxygen, by starting ignition electrically, in causing the carbonic acid resulting from the oxidising of the carbon to be absorbed in a known quantity of alkaline solution placed in the flask itself in which combustion takes place, and in determining the excess of free alkali by means of a titrated sulphuric acid liquor, in the presence of phenolphtaleine as an indicator.

The two following equations show the reactions;

$$\left\{\begin{array}{l} 4\ (Na\ OH) + 2\ Co^2 = 2\ (Na^2\ Co^3) + 2\ (H^2\ O) \\ 2\ (Na^2\ CO^3) + So^4\ H^2 = 2\ NaHCO^3 + Na^2\ SO^4) \end{array}\right.$$

Reagents required.

I. — Absorbing liquor:

$\begin{cases} NaOH = 4 \text{ grammes} \\ \text{Water} = 1000 \text{ c. c.} \end{cases}$

II. — Indicator:

$\begin{cases} \text{Phenol-phtaleine} = 1 \text{ gramme} \\ \text{Alcohol at } 90^0 = 100 \text{ c. c.} \end{cases}$

III. — Titrated sulphuric acid solution:

$\begin{cases} SO^4 H^2 = 4.083 \text{ grammes} \\ \text{Water} = \text{sufficient quantity to make up to} \end{cases}$

one litre. This liquo rcontains 3.333 grammes of SO^3 per litre and one cubic centimetre corresponds to 1 milligramme of C. The SO^3 is exactly determined as $BaSO^4$ by means of $BaCl^2$.

Description of the Apparatus.

The apparatus consists mainly of the following:

1. — A conical or cylindrical flask of about one litre capacity, of Jena glass, having a wide neck closed by an indiarubber stopper made with three openings: through these run two copper rods, fitted with ignition electrodes, and a tube, also of copper, which serves to supply the oxygen required for combustion to the top of an asbestos cup which contains the metal for analysis. The cup is carried by a bent copper rod fitted to the oxygen supply tube, by means of a slide provided with a thumb-screw, which allows regulation for height.

2. — A receiver containing oxygen under a pressure of 30 to 40 cm of water, which serves to maintain a practically constant pressure and a high oxidising atmosphere in the combustion flask, by renewing the oxygen supply according as it is being utilised in the reaction. The water in the receiver contains a little potash for removing from the oxygen all traces of carbonic acid which it might contain.

3. — A small bottle is inserted between the oxygen receiver and the conical flask, being connected to both by indiarubber tubes. This small bottle acts as a seal; it contains a small quantity of mercury through which the oxygen is made to flow, by means of a plunger tube, in passing from one to the other.

This arrangement prevents gas from being driven back into the oxygen receiver, should a too active combustion produce an excess of pressure in the conical flask.

The cups which serve to contain the metal for combustion, and have to be changed for each separate operation, are very cheaply made, by dishing circular pieces 50 m. m. (2 inches) in diameter cut out of asbestos-board 1 to 2 mm. (0.039 to 0.78 m.) thick. The dishing is very easily accomplished, by driving the circular pieces, sligthly damped, in a steel ring 30 mm. (1.180 in.) inside diameter, using a brass mandrel 25 mm. (0.984 in.) in outside diameter. The cups then undergo heating for several hours at a high temperature, in a muffle furnace in order to destroy all organic matter and to decompose the carbonates which might be found in the asbestos.

Description of the Operation.

About 1 or 2 grammes of the metal to be analysed is placed in the asbestos cup, fine drillings of the metal being used. Should the metal be in a powdered state, or in the form of large turnings, it should be mixed with 0.100 or 0.200 grammes of $Pb\,O^2$ or $Bi^2\,O^4$, in order to facilitate combustion; combustion would risk being incomplete were this precaution not taken.

The cup containing the metal is placed on its support, its position being adjusted by means of the slide and thumb-screw in such a way that its rim is at a distance of from 5 to 6 mm. (0.196 to 0.236 in.) from the opening of the tube supplying the oxygen, the points of the electrodes touching the metal turnings. The whole is then placed, in the conical flask, which has previously been filled with oxygen, on a beaker containing water in which 40 to 50 cubic centimetres of soda solution have been poured.[1]) The apparatus is carefully made tight, special care being also taken not to let any of the metal for analysis fall out of the cup; the tap regulating the oxygen supply is opened in order to establish the pressure in the combustion apparatus and an arc is produced between the two electrodes by a double-pole switch,

[1]) When the percentages of carbon are high, it is advisable to double the quantity of soda solution, in order to always have a great excess of free alkali after the absorption of Co^2.

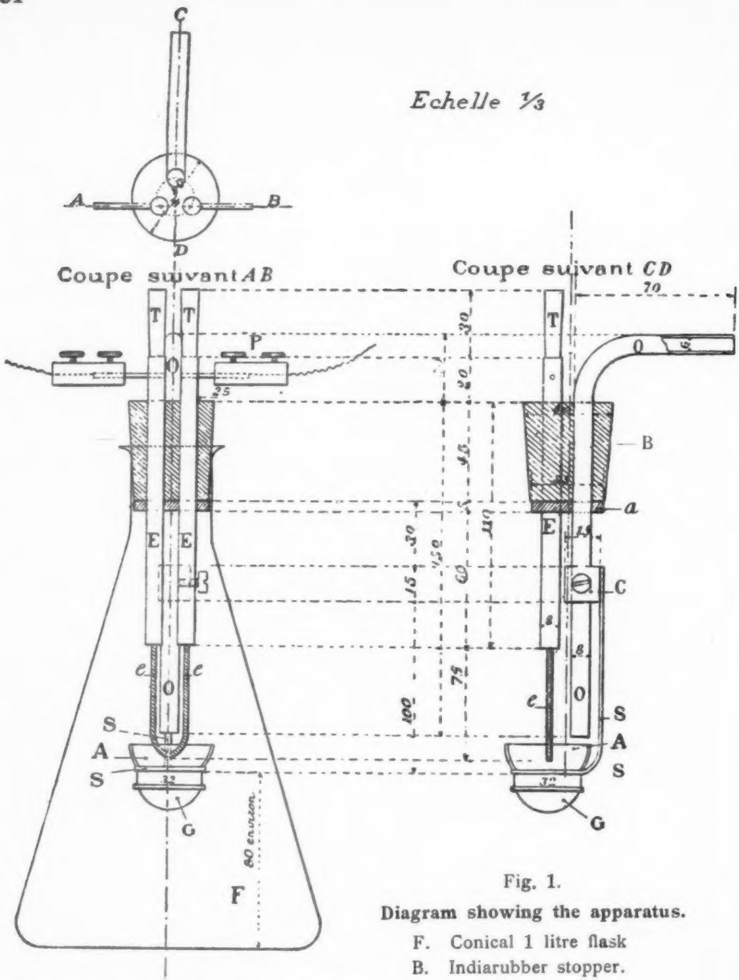


Fig. 1.

Diagram showing the apparatus.

F. Conical 1 litre flask
B. Indiarubber stopper.
a. Asbestos ring protecting the stopper.
E. Electrode carriers.
e. Electrodes.
T. Insulating fibre extensions, for varying the distance between the electrodes.
P. Current collecting rods.
O. Copper pipe for oxygen supply.
C. Slide with screw for regulating height of asbestos cup.
S. Asbestos cup holder.
G. Basket of copper netting or clay cup to contain the oxide which otherwise would fall at the bottom of the flask, when the asbestos cup became damaged.

the current intensity being limited, by means of a suitable resistance, to 12 or 15 amperes, when the electrodes are short-circuited.

As soon as combustion has started, current is cut-off and the metal generally continues burning. Should combustion cease, or proceed with difficulty, fresh sparks are created by working the switch and by causing the distance between the electrodes to vary by acting on the end pieces; the latter are made of insulating fibre and form the extensions above the indiarubber stopper of the current connecting bars. If, on the contrary, reaction is too violent, it can be moderated by stopping the supply of oxygen.

When combustion is complete, the oxygen tap is turned off, the conical flask is cooled by plunging it into water, it is then

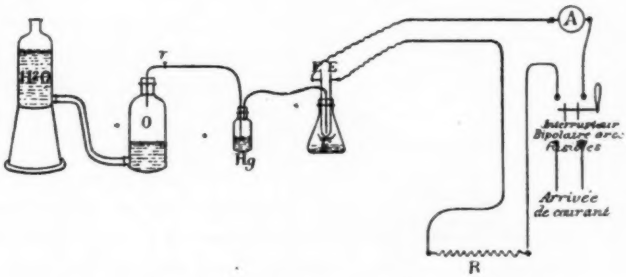


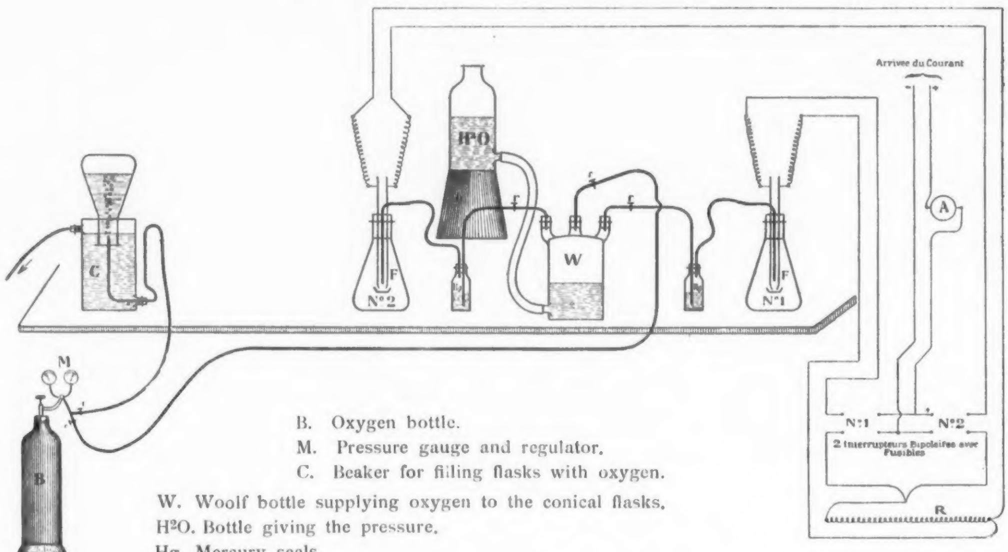
Fig. 2. — **Diagram showing arrangement of apparatus.**

H²O. Bottle giving the pressure.
O. Bottle containing the oxygen.
Hg. Mercury Seal.
A. Ammeter.
R. Resistance designed for a 12 to 15 ampere current when the electrodes are short-circuited.
r. Tap.

quickly closed by a solid stopper after removal of the lighting device; it is shaken for 5 to 10 seconds to complete the absorption of the CO^2, the alkaline liquor is poured into a glass and the excess of non-carbonated soda is determined by pouring the titrated sulphuric acid liquor into a beaker graduated in 1/10 cubic centimetres until the pink tint due to the phenolphtaleine dissappears.

The ratio between the two solutions, alkaline and sulphuric, is established and from the difference between the two titrations the proportion of carbon is arrived at, bearing in mind that if

Double installation for rapid determination of carbon.



B. Oxygen bottle.

M. Pressure gauge and regulator.

C. Beaker for filling flasks with oxygen.

W. Woolf bottle supplying oxygen to the conical flasks.

H^2O. Bottle giving the pressure.

Hg. Mercury seals.

A. Ammeter.

r. Tap.

R. Resistance designed for a **12** to **15** ampere current when the electrodes are shortcircuited.

F. Combustion flasks.

the sulphuric acid standard liquor contains exactly 3.333 grammes of SO^3 per litre, 1 cubic centimetre of this solution corresponds to 1 milligramme of carbon.

It will be noted that by proceeding thus no account need be taken of the slight carbonating — which is almost inevitable — of the reserve of absorbing solution.

The process enables the carrying out of a determination for carbon in 5 to 7 minutes, equal in precision to that obtained with the Wiborg apparatus. It is applicable to all kinds of steel, the presence of chromium, nickel, tungsten, molybdenum, vanadium, titanium, etc. leading to no risk of error.

The author has succeeded in applying the method to cast iron tests and to all iron alloys, by basing his researches upon the following observations:

1. — When the proportions of carbon are too low, the metal burns incompletely but in no case is there any carbon monoxide produced.

2. — Combustion is all the more incomplete the higher the proportion of carbon; an occurrence takes place similar to that which obtains in the cutting of metals by means of the oxygen blow-pipe, when the operation becomes gradually difficult as the proportion of carbon in the metal increases, the operation being impossible in the case of cast-iron, which melts without burning.

The remedy consisted in placing the too highly carburised metal in a larger quantity of iron or extra-mild steel; this has given perfectly good results, the addition of an oxidising body, lead bioxide, or bismuth tetraoxide also facilitating the integral combustion.

The following list gives the weights of material to be used in order to obtain exact determinations of carbon in the case of cast-irons and the various ferro-alloys:

For all cast-irons	0.500 gr. cast-iron	+ 0.200 gr. PbO^2	+ 1 gr. extra-mild steel.	
For ferro-chrome with 6 to 10% C	0.250 gr. ferro	+ 0.200 gr. "	+ 2 gr. "	" "
For ferro-chrome with 1 to 5% C	0.500 gr. "	+ 0.200 gr. "	+ 1 gr. "	" "

For ferro manganese	0.250 gr.	ferro	+ 0.200 gr.	PbO^2	+ 1 gr.	extra-mild	steel.
	0.500 gr.	"	+ 0.200 gr.	"	+ 2 gr.	"	"	"
For ferro-silicon with 10 to 90% Si	0.500 gr.	"	+ 0.200 gr.	"	+ 1 gr.	"	"	"
For ferro-Mo	0.500 gr.	"	+ 0.500 gr.[2])	"	+ 1 gr.	"	"	"
For ferro-Tu	0.500 gr.	"	+ 0.100 gr.[3])	"	+ 1 gr.	"	"	"

The very fine turnings of extra-mild steel — these are made as fine as practicable — are placed at the bottom of the asbestos cup and the mixture of pulverised cast-iron or ferro-alloys is uniformly spread over it with the powdered lead-oxide.

The pulverised cast-iron is passed through an **80**-mesh screen and the ferro-alloys through a **120**-mesh screen.

In this manner even grey cast-iron containing a large percentage of graphite is burnt completely.

Correction is made by effecting a blank test in like conditions with all the reagents, and without the metal requiring analysis; steel should be selected as low in carbon and as pure as possible ($C = 0.050$ to 0.080).

Note.

I. — When powdered hardened steels are dealt with, it is necessary. in order to effect a good combustion, to pass the powder trough a 100-mesh screen and to add **0.200** to 0.300 of PbO^2 per gramme of steel, this facilitating reaction by dividing up the material

II. — In the case of steels containing over **1.5** percent of carbon, it is necessary to have large and thin drillings obtained by drilling at high speed with a good drill. Needle shaped drillings, dust and thick shavings should not be taken, or, if taken, a combustible material should be added.

For determining the proportions exceeding 1.5 per cent of carbon it is advisable to dilute the liquor to 500 cubic centimetre

[2]) When less PbO^2 is used there occurs a volatilisation of a small proportion of molybdic acid which passes into the soda liquor and impairs titration.

[3]) With 0.200 PbO^2, combustion is too violent and the asbestos cup becomes damaged.

in order that the disappearing of the tint be quickly discernible, and it is prudent to return to the soda solution until the reapearance of the pink tint.

III. — Numerous tests have shown that S has no influence or, it should rather be said, has but a very slightly appreciable influence, even in the case of metals containing as much as 0.800 per cent of S. In determining the sulphur by means of bariumchloride in the soda liquor rendered hydrochloric, the author found only traces of bariumsulphate. The figures for the carbon were perfectly accurate and required no correction. The sulphate resulting from the oxidising should all remain in the cup whence it can be taken for purposes of determination

IV. — The same applies to phosphorus, which all remains in the cup as phosphate. Even by operating with cast-iron containing 2 per cent of P the C determinations have remained accurate and no trace of the P could be found in the soda liquor.

REPRINTED BY PERMISSION FRO THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIAT N FOR
TESTING MATERIALS".

SLAG-ENCLOSURSE.

Official Report on problem **43** by **Dr. Walter Rosenhain,** of the National Physical Laboratory, Teddington, England.

In accepting the request of the Council of the International Association for the Testing of Materials to report to the VIth Congress on the whole subject of "Slag Enclosures" the author regrets that he cannot base his Report on any extended systematic investigations of his own, undertaken for the purpose of this Report. Since he raised the question before the Congress of Copenhagen, numerous lines of investigating this problem have sugested themselves to the author, or have been suggested to him by the work of others, but circumstances beyond his control have made it impossible to take up this particular branch of metallographic research; his personal contributions to the subject are therefore confined to some isolated experiments and to the collection of data from current experience.

The subject has, however, received considerable attention from other investigators and in certain directions important progress has been made, particularly in France, America and England, so that a large amount of material is available for the present Report. Accordingly, for the sake of clearness, it is proposed to deal with the subject under systematic headings rather than by seriatim reference to the various published researches on the subject. It is hoped that this method of treatment will result in a clear representation of the present state of the subject, and this is aimed at rather than a precise account of the work of each investigator. This method has the further advantage that it makes it easier to deal with the whole subject in an objective manner and to avoid the risk of appearing to criticise — adversely or otherwise — the work of any given author.

The headings under which the subject may be grouped are as follows:

1. Nomenclature.
2. The study of the Constitution of the Enclosures.
3. The mode of formation and origin of the Enclosures and suggested methods of prevention.
4. The distribution of the Enclosures in steel and their effects on the properties of steel.
5. Suggested directions for the further investigation of the subject.

1. **Nomenclature.** The term "Slag-Enclosures" under which title the author's Copenhagen paper was presented to this Association, has been adversely criticised in several directions. It has been pointed out that particles of sulphide of manganese cannot properly be described as "slag" since neither acid nor basic slag consists of this substance. Strictly and literally speaking this objection holds good, at least so far as sulphide of manganese is concerned; on the other hand a somewhat wider interpretation may perhaps be allowed for the term "slag." Thus the term „slag enclosures" has been rendered in French as "inclusions des scories", and the use of the term "slag" in this connection is justified if we extend it to include all the fluid or semi-fluid non metallic matter which is formed in contact with or is thrown off by steel during the melting and teeming operations. Any particles of such matter ultimately found in the steel may fairly be termed "enclosures" since — given time and other favouring conditions — they would have been expelled from the steel; they are enclosed by the "accident" that the steel has become solid before their escape was effected. Used in this sense, the term "slag enclosures" does not necessarily imply that the bodies in question are particles of actual surface slag which has become stirred up with or mechanically entangled in the metal although the author sees no reason to doubt that such is the origin of at least some of the enclosures met with in commercial steels.

An alternative name for these bodies has been suggested by H. D. Hibbard (1) in a paper entitled "The Solid Non-Metallic Impurities in Steel". This title is abbreviated by compounding the initials of certain of these words to form the coined word

"Sonim". Many objections may, however, be raised against this ingeniously-coined term. Like all such coined words it is meaningless in itself and a somewhat elaborate explanation would be required by the uninitiated. Those who have literary inclinations, again, will hesitate to add such a coined word to our already over-burdened technical slang. Further, the full term "Solid-Non-Metallic-Impurities" is itself open to objections. Thus Hibbard sugests that these bodies should be studied in their origin in the hot, molten steel, yet in those circumstances they can hardly be called "solid". Again, the question arises as to the distinction between "metallic" and "non-metallic" impurities. Hibbard classes sulphides as non-metallic but includes iron phosphide as metallic, and it is not easy to see how this distinction can be justified, while if we class the phosphide as also non-metallic it becomes difficult to draw a line between the phosphide and the carbide. The only sound line of demarcation would seem to lie between those bodies which are soluble in the steel when sufficiently heated and those which are not. The solubility of iron carbide at high temperatures is, of course, undoubted, but with regard to the other bodies, opinion is not entirely undivided; thus Zigler (2) takes the view that the sulphides and silicates are soluble in hot steel and in regard to oxides he speaks of the existence of eutectics.

In view of the difficulties which thus appear to beset the nomenclature of this subject, the writer prefers for the present to retain the term "slag enclosures", although in the text of the present Report it will be permissible to employ the simple word "Enclosures" without risk of misapprehension.

2. **The Study of the Constitution of the Enclosures.** This fundamentally important branch of the subject has received important contributions from Matweieff (3) and Levy (4). The former deals essentially with the methods available for identifying the various forms of enclosure met with in metallographic sections of steel, while the latter has undertaken the synthetic study of some of the more important enclosures.

The method of Matweieff consists in synthetically producing enclosures of known constitution and studying their behaviour under various reagents, and then applying the results so obtained to the examination of the enclosures met with in practical examples.

The list of chemical entities considered by Matweieff consists of the oxides of iron and manganese, the silicates of iron and manganese (FeO, SiO_2, $2FeO$, SiO_2 and MnO, SiO_2 and $2MnO$, SiO_2) and the sulphides, MnS and FeS. Except in the case of the oxides, this author does not appear to consider the possibility of the existence of mixtures or mutual solutions of two or more of these bodies and for that reason the results of his research will require re-examination in the light of later researches.

Synthetic enclosures of the various bodies named above were prepared by Matweieff, in most cases by filling a small hole drilled into a piece of wrought iron with the powdered substance, then plugging up the hole with an iron plug and heating the whole to a sufficiently high temperature. Systematic examination under the ordinary fluid reagents used in Metallography showed — what the experience of metallographic study of steel would have led one to anticipate — that with the exception of the sulphides, all the "enclosures" were equally unaffected. The sulphides are, as is well known, attacked by very dilute mineral acids, and the method of sulphur-printing as devised by Heyn and modified by Baumann for the localisation of sulphide enclosures, is widely practised.

Finding the liquid reagents by themselves inadequate for the study of the enclosures Matweieff turned his attention to the use of gaseous reagents at more or less elevated temperatures, the gases employed being hydrogen and superheated steam. In addition to these he also found the use of weak organic acids (liquids) desirable for the purpose of distinguishing between sulphides and silicates. According to their behaviour under these reagents, the enclosures may be divided into three groups or classes.

A. Stable bodies which are not acted upon either by hydrogen at 300° C, by superheated steam, or by weak organic acids. These are the silicates of iron and manganese.

B. Bodies which are reduced to the metallic state by the action of hydrogen at 300° C and are acted upon by steam but are unaffected by weak organic acids. These are the oxides of iron and manganese. Oxide of manganese is not reduced by hydrogen when by itself, but in the presence of iron oxide reduction of both metals takes place. On re-polishing a sample after heating in hydrogen, the regions previously occupied by

oxides appear as bright metal, like the ferrite of the surrounding iron or steel, but the presence of manganese may be detected by etching with very dilute alcoholic solution of ferric chloride. Iron free from manganese is only very slightly coloured, but if manganese is present, the reagent produces rapid colouration.

C. Not affected by hydrogen or steam, but attacked by weak organic acids (such as tartaric acid). These are the sulphides of iron and manganese; the former is rapidly coloured by this acid while sulphide of manganese is only slowly attacked. The behaviour of the sulphides which are mixtures or solid solutions of the iron and manganese sulphides is not considered by Matweieff, but in the light of the work of Levy these mixed sulphides require particular study from this point of view

The use of hydrogen for the purpose of reducing the oxide enclosures met with in metallographic sections of iron and steel had been successfully used some time before the publication of Matweieff's paper by Rosenhain and Humfrey (5) who identified certain black specks found in the sections of annealed soft sheet steel as oxides by this method.

Metallographic workers who have previously found themselves faced with the difficulty of identifying the chemical nature of the enclosures present in the iron and steel micro-sections which come under their notice will at once appreciate the value and importance of the systematic means of determining the nature of these bodies which Matweieff's work has placed at their disposal, but this appreciation will be tempered by the fact that the use of gaseous reagents at moderately high temperatures is a somewhat cumbrous manipulation, particularly because, if general tarnishing of the polished specimens is to be avoided, the hydrogen must be specially purified. It is to be hoped, therefore, that future research may yet find simpler means of identifying these substances.

D. M. Levy (4) has particularly studied the sulphides of manganese and of iron and the silicates of these two metals, largely by preparing these bodies synthetically and studying them by means of thermal and microscopic observations. The value of such a method of investigation is obviously very great and this pioneer work of Levy although admittedly far from furnishing a complete or conclusive account of these substances has taken the subject sufficiently far to indicate that results of the highest

importance are to be anticipated by a further pursuit of this branch of investigation.

Levy began by studying the sulphide of manganese, and found that to obtain complete fusion of this substance a temperature upwards of 1450^0 C was required; even at that temperature he describes the resulting melt as "exceedingly viscous and plastic". He fails, however, to find any arrest on the cooling-curve of this substance, presumably taken from a temperature at which he describes it as completely fluid. If this observation is strictly correct it would point to the fact that the pure sulphide of manganese is really a slag-like, vitreous substance which does not solidify by cristallization but simply congeals without passing through any critical change and remains as an under-cooled liquid, such as glass and other vitreous slags. In sharp contrast to this idea, however, are Levy's statements as to the crystaline character of the fused sulphide. He describes it as "silver grey in colour, highly crystalline, possessing a brilliant metallic lustre, and in appearance closely resembling high-grade copper matte". "The silver grey crystals are readily powdered forming a bright green powder. It appears to cristallise in the cubic system — —". These statements taken together with the supposed absence of any heat-evolution during cooling, appeared to the present author so remarkable that — as a preliminary step towards a complete study of the equilibria of iron and manganese sulphides — he undertook several fusions of pure manganese sulphide. These fusions were carried out in a crucible prepared by boring out a rod of pure graphitic carbon, and this crucible was heated in a carbon-tube electric resistance furnace heated by an alternating current of from 300 to 400 amperes[1]). The atmosphere in the tube furnace was kept neutral by passing through the tube a fairly rapid current of pure dry nitrogen, so that the only oxygen present was that derived from the air entangled in the fine mangenese sulphide powder with which the crucible was charged. Thermo-electric measurements of the temperatures were not made in these preliminary experiments, but the temperature of the crucible was observed by means of an accurately-calibrated optical pyrometer.

[1]) The author is indebted to this colleague at the National Physical Laboratory, Dr. J. A. Harker F. R. S. for placing at this disposal the furnace in which these fusions were effected.

The condition of the contents of the crucible was ascertained by means of a thin carbon rod which passed through the carbon stopper which closed the upper end of the furnace tube. At first this rod rested upon the surface of the powder with which the crucible was filled, but at a well-marked temperature the rod sank down to the bottom of the crucible. On moving it about the contents of the crucible were then found to be somewhat viscous,

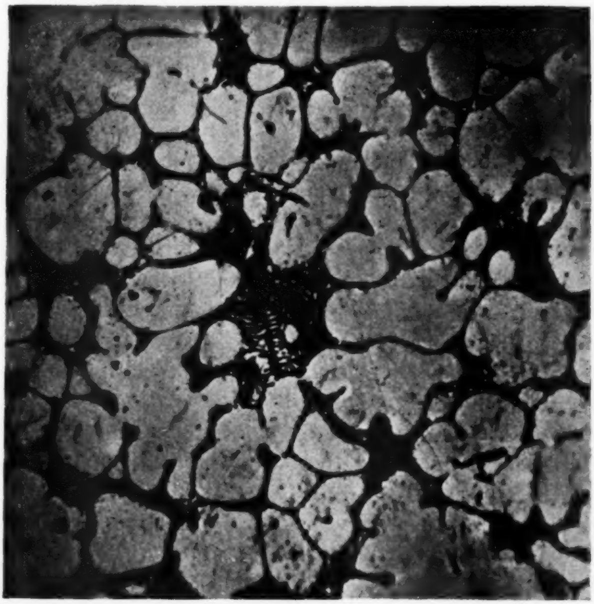


Fig. 1. Micro-section of small ingot of fused sulphide of manganese. Magnification 150 diameters.

but as the temperature rose further the resistance of the crucible contents to the movements of the rod became negligible, and observations with the optical pyrometer showed that this occurred consistently at a temperature close to 1320° C. The temperature of the furnace was never carried beyond 1350° C, and on allowing the apparatus to cool it was found that sensible resistance to the movement of the carbon rod in the crucible began at a temperature lying between 1320° and 1310° C while at the same time a decided

diminution of the rate at which the temperature of the crucible fell was also observed. These observations were repeated several times and appear to indicate with some certainty that the sulphide of manganese used in these experiments (purchased as pure MnS from Kahlbaum) melts and freezes at a temperature not far removed from 1315° C and that there is probably a heat-evolution near this temperature on cooling. There is, however, some reason to doubt whether the molten mass in this experiment was really pure MnS, since in spite of the care taken to render the conditions of heating as neutral as possible, there was a decided evolution of fumes from the furnace and for a short time there was a decided odour of sulphur dioxide. This suspicion that some chemical action had taken place to a small extent is supported by an examination of the micro-structure of the small ingot produced in this experiment. This ingot in character and appearance coincided accurately with Levy's description quoted above, but the micro-structure differs decidedly from that shown by Levy. In Fig. 5 of his paper, Levy shows the structure of pure fused MnS as seen on a polished but un-etched section to consist of angular polygonal grains separated by slightly discontinuous films of a darker substance, but this darker constituent exhibits no sign of a duplex structure. The micro-structure of the author's ingot is shown in Fig. 1 which shows light-coloured polygonal grains or crystals embedded in a beautifully-marked and very typical eutectic. The specimen photographed has been etched for a short time in very dilute hydrochloric acid dissolved in alcohol and this action resulted in the decided blackening of the minor constituent of the eutectic, which had already been visible — although somewhat dimly, in the polished specimen before etching. Since the bulk of the specimen in question consists of MnS, it is surprising to find that there is n the eutectic a constituent which etches more rapidly in a dilute acid than MnS — since it is evident on careful examination that the white and not the dark constituent of this eutectic is identical with the primary crystals of MnS. Whatever the exact nature and composition of this eutectic, however, it is obvious that the approximate determination of the melting and freezing temperatures of this substance must be affected by its presence to a considerable extent so that the true freezing-point of pure MnS is certainly higher, and may even be very considerably higher than the

temperature (1315° C + 5) which has been found in the experiment in question. It seems unlikely, however, in view of the comparatively small proportion of the eutectic present, that the true meltingpoint of the pure sulphide should be much higher than 1350° C.

The melting-point of manganese sulphide has also been studied by Fay (5) who also melted pure manganese sulphide in an electric furnace, his atmosphere being formed by a current of hydrogen sulphide. By means of a thermo-couple he finds the freezing-point to be 1162° C, but the nature of the crucible employed is not stated. Fay appears to think that in his experiment the freezing-point was lowered by the presence of free manganese in the molten product, and in view of the reducing athmosphere which he employed this appears probable. Fay's remark, however, that the solubility of manganese in manganese sulphide is indicated by the fact that the colour of the sulphide enclosures varies according to the amount of manganese present in the steel, is explained equally well by Levy's demonstration of the mutual solubility of the sulphides of manganese and of iron.

The observations of Levy and Fay, and those by the present author which have just been described point clearly to the necessity of a thorough study of the equilibrium diagram of the system MnS — FeS. Such an equilibrium diagram, however, is obviously merely a section along one particular line of the ternary equilibrium model of the system Fe — Mn — S and it remains to be proved whether the simple melting together under neutral conditions of mixtures of pure Mns and pure FeS will be sufficient to afford the required information. If the two compounds remain entirely un-dissociated during their mutual fusion, solution and solidification, then such a proceeding may be satisfactory, but it is more probable that it will be necessary to study accurately the equilibria over a narrow strip of the ternary triangle lying upon either side of the MnS — FeS line. This is a large task, but one which the present author hopes to be able to undertake, as he regards an accurate knowledge of these equilibria as being of fundamental importance for the whole question of sulphide enclosures.

Levy's preliminary study of these equilibria has shown that MnS possesses the power of retaining FeS in solid solution up to close upon 50 per cent. This result is of importance in two respects;

it indicates that even if the amount of manganese present in a steel is less than sufficient to take up all the sulphur, yet the manganese sulphide which is formed will be able to hold in solid solution very nearly its own weight of sulphide of iron. How far this mixed sulphide approximates in its properties and behaviour to that of pure or nearly pure MnS yet remains to be determined; it may be that as regards the vital question of distribution in the steel such a solution of the two sulphides — which is probably more fusible than either sulphide alone, may behave more like FeS than like the decidedly less harmful MnS. On the other hand, from the analytical and micrographic point of view the existence of these mixed sulphides is of importance since it is likely to affect their behaviour to reagents and their microscopic appearence as compared with that of pure manganese sulphide.

Levy has also studied the silicates of manganese, and describes three varieties, viz. two forms of the mono-silicate ($2\,MnO\;SiO_2$) and one of the tri-silicate $2\,MnO$, $3\,SiO_2$. These bodies are all vitreous in character but show more or less definite arrests on solidification and in the case of the mono-silicate, also several arrests at lower temperatures. These arrests must, in the opinion of the present author either indicate that these silicates realy crystallise and are not truly vitreous, or — and this seems more probable — that at the temperatures of these heat-evolutions certain kinds of crystals are deposited which differ in composition from the vitreous mother-substance, so that the solidified mass is a conglomerate of crystals embedded in a vitreous matrix. Levy gives no microscopic evidence as to the nature of these bodies. On the other hand he gives definite data as to their freezing-points; that of the mono-silicate is 1300^0 C, but this is lowered to 1120^0 C by the addition of one per cent of iron. The arrest on the cooling-curve of the tri-silicate is found at 1255^0 C. Since these silicates probably resemble other well-known silicates in their power of forming mutual solutions and of forming vitreous solids on cooling, the study of the equilibria of these bodies together with the other silicates likely to be met with in steel and in the slags is again of considerable metallurgical interest, although probably a field of extreme difficulty. Levy has studied the solubility of manganese sulphide in manganese silicate in mixtures

of the two substances containing up to 50 per cent of sulphide and up to this concentration the two substances are completely miscible in the fluid state. Apparently, however, the sulphide is almost entirely rejected from solution on cooling, since even with a sulphide content of only one per cent Levy states that "it is just possible to recognise globules of sulphide". With higher proportions of sulphide present, micro-sections show well-formed dendritic crystals of sulphide in a matrix of silicate, and these exhibit appearances which closely resemble the structures met with in duplex enclosures in steel. The work of Levy thus clears up, at least in general terms, the constitution of these duplex enclosures.

An important question concerning the nature and constitution of the enclosures found in steel is that of their solubility or otherwise in hot or in molten steel. This question fundamentally affects our conceptions as to the origin of these bodies and their behaviour during the freezing and subsequent cooling of the steel, and — most important of all — the means to be adopted for their elimination. If these substances are soluble in molten steel even to a small extent, then it is practically impossible to eliminate them entirely; on the other hand it has been widely assumed — perhaps on insufficient data — that the sulphides and silicates are totally insoluble in molten steel and that their condition is purely one of mechanical suspension. The possibility is certainly worthy of consideration whether there may not be a certain slight solubility of silicates and sulphides in molten iron and that this solubility may rise perceptibly with increasing temperature above the melting-point. In that case, the enclosures would be separated from the molten steel during the cooling process which occurs prior to the actual filling of the moulds. A part of the separated bodies would have time to rise to the surface and join the slag, but the remainder would be frozen in situ in the solidifying metal. It is evident also that the question of such solubility at extremely high temperatures must materially affect the mode of action of the additions made to steel in the furnace or in the ladle; given such solubility everything would depend upon the temperature at which the additions were made and then on the temperature to which the steel was allowed to fall before the moulds were filled.

3. **The Mode of Formation of the Enclosures and Methods for their Prevention.** The considerations just discussed come strictly under the present head but have been dealt with under the previous section since they arise directly from questions as to the nature and constitution of the bodies themselves.

The mode of origin of the enclosures is very fully discussed by H. D. Hibbard, and as a result of his discussion — which is based on general considerations of a more or less theoretical nature and not on any special experimental grounds, he arrives at the conclusion that the formation of the enclosures is due almost entirely to the "washing" action of the additions, principally of manganese, in combining with the dissolved oxides, sulphides and silicates which are present in the steel at the end of the melting process before the manganese is added. One experiment is described in which the usual manganese addition was replaced by an addition of ferro-silicon, with disastrous results so far as the quality of the steel was concerned. Now the high manganese content of the majority of the enclosures is generally admitted, and therefore in the case of steels in which the greater part of the manganese is derived from additions put into the steel in the ladle, it follows that these enclosures are formed in the ladle or subsequently. In favour of the latter view there is the opinion of J. E. Stead that the silicate enclosures at all events are due to oxidation of manganese and silicon occurring during the passage of the molten steel through the air in passing from the ladle into the moulds. Hibbard rejects this view as improbable. The question could be advantageously studied by examining the state of the steel as regards enclosures as it exists in the ladle before the additions are made. Either by filling a small mould with the steel in this stage, or even by filling a large sampling ladle and subsequently examining the metal microscopically and comparing the enclosures with those to be found in the same steel after the manganese had been added, definite conclusions could be obtained on this point. As regards sulphides, of course, facts of this kind are already well ascertained, but as regards the silicates the matter is still somewhat an open one. A recognition of the exact mode of origin of these enclosures — of the precise stage in the steel making process at which they arise — is the first step towards the elimination of these substances.

An important question in this connection arises as to the solubility or otherwise of iron oxide in molten iron or steel. The presence of minute particles of oxide has been recognised under the microscope and their nature has been demonstrated by the reducing action of hydrogen, but there is an important distinction in this matter between oxide which is present merely in suspension and oxide which has been separated from solution. In the case of copper the existence of solubility of the oxide in the molten metal is well estabilished and the formation of a well-defined eutectic of copper and cuprous oxide has been demonstrated by Heyn (6). Ziegler (2) speaks of such an eutectic in the case of iron and iron oxide as a matter of course, but gives no definite evidence of its existence. Perhaps the only sound method of determining this important point is by a more accurate study of the freezing-point of pure iron; if this freezing-point is materially affected by the presence of oxide in contact with the molten metal then we are justified in concluding that there is a corresponding degree of solubility, but if the freezing-point is not affected the probability of any sensible solubility is remote. The facts at present known do not afford the necessary data, since the determinations of the freezing-point (see paper by H. C. H. Cappenter (7) have all been made under moderately exidising conditions, while the extreme degree of purity essential for the detection of the possibly minute thermal effects of oxygen has not yet been attained. So far as the data go, however, the comparative concordance of the freezing-point of pure iron as obtained by various observers under differing conditions suggests that the effect of oxide in lowering the freezing-point is at all events not large. On the other hand the decarburization of steeel heated in contact with oxides of iron suggests that not only the iron-carbide but probably also some form of oxygen-bearing substance is capable of diffusing through the steel. In the present connection a knowledge of the exact solubility relations of iron and its oxides at different temperatures is of very considerable importance as affecting our knowledge of the mode of formation of enclosures such as silicates and oxides, so that stress has been laid on this aspect of the subject in order to bring it to the notice of investigators.

From what has been said above, it would seem that our knowledge of the mode of formation of the enclosures met with

in steel has not yet advanced far enough to make it possible to put forward definite rules for their more or less complete elimination. It is evident, however, that the two elements, oxygen and sulphur are principally responsible for their presence in the finished steel, while the action of manganese tends to reduce the quantity of enclosures and to lessen their harmful nature. On the other hand, it is evident that in steel-making processes which depend on oxidation of the carbon either by an air-blast or by the oxygen of the ores, the presence of oxygen cannot be entirely avoided, and this carries with it the formation of silicates. Our knowledge of the sulphides and silicates of manganese, however, is now sufficiently advanced to enable us to state that in molten steel those bodies are probably present as liquid globules and in order to minimise the quantity of enclosures it is only necessary to adopt those methods which are known to aid the elimination of enclosed globules of foreign liquids from a much denser fluid. These conditions are that the globules in question shall be caused to coalesce in such a way as to form few large globules instead of very numerous small ones, and that time be given to allow these globules to rise to the surface. The latter condition appears to be chiefly a question of works economy, and it is likely to be more widely considered if the desirability of eliminating the enclosures is more fully recognised. The former condition is much more difficult to fulfill, and probably requires very careful investigation. We may, perhaps consider the shomewhat analogous problem of the rapid elimination of gas-bubbles from molten glass; the time required for such bubbles to rise to the surface if the bubbles are small is excessively long, and very fine bubbles will never rise at all. The glass-maker avoids this difficulty by two methods; he adjusts his glass composition in such a way that very small bubbles are never formed, and secondly he assists the smaller bubbles to rise by causing the molten glass to "boil" by pushing into it some substance which gives off large volumes of gas — such as a wet potato. It is possible that analogues to both methods might be applied to steel — the exact time and temperature at which additions are made may be found to influence the size of the resultant globules of manganese sulphide and silicate, while it may also be found possible to agitate the steel by some artificial means. It would seem that, at all events, there

are possibilities of an advance in these directions which are worthy of consideration.

4. Distribution of the Enclosures in Steel and their Mechanical Effects. The distribution of the enclosures, which is obviously dependent upon their mode of origin, has heen studied by both Hibbard and Ziegler (1 and 2). The former author calls attention to the fact that the importance of a given volume of enclosures depends upon their distribution — in the form of minute globules he considers that they are of minor importance, but in the form of thin films on the crystal junctions he regards them as dangerous even if present in quantities too small to be recognised with the microscope.

Ziegler puts forward an explanation for the observed fact that the enclosures are usually found in the ferrite areas of hypo-eutectoid steel and in the cementite areas of hyper-eutectoid steels. It is a little unfortunate that this author bases his explanations on a conception of the manner in which steel undergoes transformation on cooling from the molten state which differs from the generally accepted views and is, indeed, incompatible with the general laws of heterogeneous equilibria. This view — that steel when it first solidified does not at once form an aggregate of crystals of austenite, but that such crystals are only separated at a temparature slightly higher than Ar_3 — does not, however appear to be fundamentally necessary to Ziegler's further interpretation of his observations. While on Ziegler's view the whole of the elements present in the hot steel form one homogeneous solid solution which begins to break up into gamma-iron crystals and particles of other substances (enclosures) at temparatures just above Ar_3, the principal facts are fitted equally well by the more orthodox view that the enclosures are not soluble in the steel at all events below the solidus line of the equilibrium diagram, but are forced — by the crystallising austenite — into the junctions between the growing crystals, although some of the globules are no doubt trapped and entangled among the dentritic spines which are first formed by these crystals. This view still leaves the enclosures at the point where Ziegler's observations require them to be, viz. in the boundaries of the original austenite crystals. According to Ziegler — and the observations which he describes

and quotes are very striking — these enclosures serve as neuclei or centres of crystallization upon which the alpha iron which, on further cooling, is separated from the austenite, begins to deposit. Just as we find the crystals of a saturated aqueous solution forming by preference upon any foreign bodies which may be suspended in the liquid, so we find the ferrite (or cementite) depositing upon these enclosures of "foreign" matter. Ziegler has thus suggested a reasonable explanation for the fact that the ferrite in slightly hypo-eutectoid steels is principally located in the form of a network which represents the boundaries of the previously existing austenite crystals. Two difficulties, however, yet remain to be explained in a satisfactory manner. The first of these is the fact that when the austenite crystals are caused to increase in size by heating the steel to a higher temperature apparently the enclosures are pushed along into the boundaries of the larger crystals — since the prevalence of the enclosures in the ferrite network is not confined to any particular grain-size which the steel may possess. If the enclosures are forced into the interstices of the austenite crystals originally formed on solidification from fusion, it is not very easy to see how they can travel through the steel in order to remain in the boundaries of the austenite crystals through all the vicissitudes of mechanical and thermal treatment which the steel may undergo. Ziegler's hypothesis that the enclosures are soluble in the very hot steel would, of course, account for this behaviour, but the fundamental fact of such solubility requires direct proof, by such methods as hot-etching or quenching, before it can be accepted. On the other hand there are some considerations which may indicate that the enclosures are not in reality so mobile as might be imagined. Thus, although we usually find the enclosures in ferrite, it does not necessarily follow that the ferrite reticulation in which we find it corresponds with the last-formed set of austenite boundaries; a tendency has in fact been observed for the recurrence, after heat-treatment, of the reticulation previously existing. Thus in the case of "burnt" steel Stead has shown (9) some time ago, that networks of enclosures produced by burning persist after heat-treatment which has entirely broken up the previous ferrite reticulation. Again, we commonly find in commercial steel a banded arrangement of ferrite and pearlite, such as that shown in Fig. 2 and although

this is obviously traceable to the rolling process which the steel has undergone, the banded structure is extremely persistent in spite of repeated annealing. If we consider that the enclosures present in the steel have been rolled out into long lines, and that each time the steel cools down through Ar_1 the ferrite tends to deposit upon these lines of enclosures, the persistent recurrence of these

Fig. 2. Typical banded structure of rolled mild steel. Magnification 100 diameters.

bands is explained. Heat treatment could, in that case, only destroy these bands if time enough were allowed for the gradual migration of the enclosures at a high temperature — and very prolonged annealing does break up the banded structure. The occurrence and persistence of the comparatively wide carbon-less bands, studded with enclosures, which are sometimes termed "ghosts" may be accounted for in a similar way by the original rolling

out into a long band of an austenite boundary containing a comparatively large mass of enclosure.

Another example of the comparative immobility of enclosures is to be found in the long lines of "slag" or "cinder" to be seen in wrought iron. These are elongated by rolling, and persist in their elongated form through a very considerable amount of prolonged annealing.

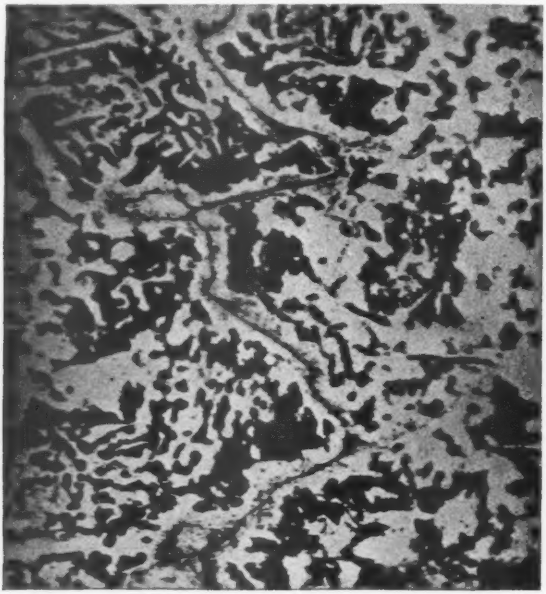


Fig. 3. Crack in steel axle, following the line of "Enclosures". Magnification 350 diameters.

The considerations which have just been discussed, although leaving many points to be determined by future research, yet indicate the importance of the fact pointed out by Ziegler, that the enclosures of "foreign" matter in steel exert a very profound influence on the micro-structure of the steel. Their indirect influence on the mechanical properties of the material is thus evident even in cases where their quantity may not be sufficient to affect the strength of the material directly.

The effect of enclosures on the mechanical properties of steel has been considered and discussed by a large number of authors and only a few of the papers can be referred to in the present report. It is, however, correct to state that there appears to be a growing concensus of opinion in the direction of regarding the presence of enclosures as seriously deleterious to the steel. One of the few exceptions to this statement is the expression of

Fig. 4. Cracks and Enclosures in a broken steel spring. Magnification 300 diameters.

opinion by J. E. Stead, in the discussion at the Copenhagen Congress, that the presence of enclosures in comparatively small quantities was of no serious effect on the properties of the steel. On the other hand L. Guillet and others quoted cases of extreme brittleness in steels due to the presence of enclosures. The injurious effects of these bodies have since been discussed in some detail by Hibbard in the paper already cited, by Ziegler and — in greater detail and with considerable experimental data — by Fay

in his paper on "A Microscopic Investigation of Broken Steel Rails: Manganese Sulphide as a Source of Danger". In this paper, Fay shows the manner in which cracks are originated in the enclosures, by breaking previously polished specimens in such a way that the course of the crack can be traced. To the cases cited by Fay, a large number of others may be added, such as those quoted by Oberhoffer (**10**), Primose (**11**) and a number which have come under the notice of the present author. As an example of the latter, the case illustrated in Fig. **3** may be given this represents a crack found in a railway axle which had broken in service, and the manner in which this crack follows the path of minute enclosures is very striking. Another striking example from the author's own practice is the case of a laminated railway spring which failed in service, and on examination was found to be seriously cracked in the vicinity of numerous large enclosures A photo-micrograph of some of these enclosures is given in Fig. **4**. The cracks in this case were evidently formed during hardening, and the danger arising from the presence of enclosures in steel which is to be quenched is thereby illustrated.

While there is thus ample evidence to justify the view that enclosures are harmful to steel and may in certain circumstances become dangerous defects, there is some need for caution in ascribing actual failures to the presence of enclosures in every case where the latter are met with in the broken object. In all commercial steel derived from either the Bessemer or the Open-Hearth processes, enclosures are present in greater or less degree, and it is easy simply to ascribe to them every case of failure met with. There are, however other causes of brittleness in steel — such as those recently studied by Humfrey (**12**) and where it is found that the brittleness of the steel is inter-crystalline — i. e. where the fractures run along the crystal boundaries and not through the crystals — such other causes should be carefully looked for. From Ziegler's work we know that the enclosures are embedded, as neuclei, within the crystals of alpha iron in the steel, so that fractures runnig along the boundaries of the alpha-iron crystals can hardly be ascribed to the presence of these bodies.

5. **Suggested Directions for Further Investigation.** These have already been indicated in each of the sections of this Report, so that they need only be briefly summarised here.

As regards the study of the constitution of the enclosures, the further study of the sulphides and silicates of iron and manganese and oi the constitution of the mixtures or "alloys" of these substances is urgently needed in order to afford a more complete understanding of the nature of the enclosures met with in steel. The question of the solubility or otherwise of the oxides of iron in iron at various temperatures is another matter requiring study, and the possibility of approaching this question by a closer study of the freezing-point of pure iron has been suggested. Similarly, the question of the solubility of sulphides and silicates of iron and of manganese in steel at high temperatures requires further research, while finally the further collection of data regarding the mechanical effects of enclosures is desirable, both from cases of failure occurring in practice and also from tests made for this special purpose either on materials met with in practice or specially prepared.

In conclusion the author wishes to point out that the present Report cannot claim to be an exhaustive account of the work done on this subject even during the past three years, but in so far as such work has come under his notice, he has endeavoured to summarise it as clearly and impartially as possible, dwelling as much on the doubts and difficulties which call for further investigation as on the solid achievements of new knowledge attained by the various authors. He hopes that at least the Report may serve again to direct the attention of metallurgists and of engineers to this subject.

(1) Hibbard, H. D. "The Solid Non-Metallic Impurities in Steel" (Sonims). Bulletin of the American Institute of Mining Engineers. April 1911. p. 325.

(2) Ziegler. "Sur la Crystallisation du Fer Alpha". Revue de Métallurgie, vol. 8, No. 9. September 1911.

(3) Matweieff. Etude Métallographique des Scories du Fer et de l'Acier. Revue de Métallurgie. 1910. p. 447.

(4) Levy D. M. "A study of the Manganese Sulphides and Silicates in Steel". Journal of the Iron and Steel Institute. 1911. 3.

(5) Rosenhain & Humfrey. "The Crystalline Structure of Iron at High Temperatures". Proceedings of the Royal Society of London, 1909.

(6) Fay, H. "A Microscopic Investigation of Broken Steel Rails: Manganese Sulphide as a Source of Danger". Proceedings of the American Society for Testing Materials. Vol. 8, 1908.

(7) Heyn E. "Kupfer und Sauerstoff". Mitteilungen des Königl. Materialprüfungsamtes Berlin, 1900. p. 315.

(8) Carpenter, H. C. H. "The Freezing Point of Iron". Journal of the Iron and Steel Institute. 1908, 3. p. 290.

(9) Stead, J. E. & A. W. Richards. "Overheated Steel". Journal of the Iron and Steel Institute, 1905, 2. p. 84.

(10) Oberhoffer, P. "Die Bedeutung der Metallographie für die Eisenindustrie". Stahl und Eisen, 1910. Nr. 6.

(11) Primrose, I. S. G. "Metallography as an Aid to the Engineer". Transactions of Glasgow Technical College. Vol. 5, 3. December 1910.

(12) Humfrey J. C. W. Carnegie Scholarhisp Report. Journal Iron and Steel Institute. 1912.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

THE NOMENCLATURE OF THE MICROSCOPIC SUBSTANCES AND STRUCTURES OF STEEL AND CAST IRON.

Report of Committee 53,

presented by the Chairman **H. M. Howe** and the Secretary of the Committee **A. Sauveur.**

The Committee for studying this problem is constituted as follows:

Professor H. M. Howe, Chairman, New York.

Professor Albert Sauveur, Secretary, Boston.

Members: F. Osmond, Paris; Dr. H. C. H. Carpenter, Manchester; Prof. W. Campbell, New York; Prof. C. Benedicks, Stockholm; Prof. F. Wüst, Aachen; Prof. A. Stansfield, Montreal; Dr. J. E. Stead, Middlesborough; Prof. L. Guillet, Paris; Prof. E. Heyn, Berlin-Lichterfelde; Dr. W. Rosenhain, Teddington.

I. General Plan.

We first enumerate the substances of such importance as to warrant it, indicating roughly their constitution, and then define and describe certain of them.

The conditions which we meet are (1) that we need definitions on which all can agree; and this implies that they must be free from all contentious matter, and be based on what all admit to be true. (2) That the reader must needs know the current theories

as to the constitution of these substances, and these theories are necessarily contentious. We meet these conditions by the plan of giving (1), the Name which we recommend for general use, followed immediately in parentheses by the other names used widely enough to justify recording them; (2) the Definition proper, based on an undisputed quality, e. g that of austenite which we base on its being an iron-carbon solid solution, purposely omitting all reference to the precise nature of solvent and solute; and (3) Constitution etc. etc., in which we give the current theories as to the nature of solvent and solute and appropriate descriptive matter.

The distinction between these three parts should be understood. (1) The Names actually used are matter of record and indisputable. (2) The Definitions are matters of convention or treaty, binding on the contracting parties, though subject to denouncement, preferably based on some determinable property of the thing defined as distinguished from any theory as to its nature, or if necessarily based on any theory it should be a theory which is universally accepted. It is a matter purely of convention and general convenience what individual property of the thing defined shall form the basis of the definition. The name and the definition should endure permanently, except in the case of a definition based on an accepted theory, which must be changed if the theory should later be disproved. (3) Theories and Descriptions are not matters of agreement or convention but dependent on observation, and therefore always subject to be changed by new discoveries. They are temporary in their nature, as distinguished from the names and definitions which should be fixed, at least relatively.

This case of austenite illustrates the advantage of non-indicative names. The names which we propose to displace, "gamma iron" and "mixed crystals", imply definite theories as to the nature of austenite, and hence might have to be abandoned in case those theories were later disproved. The name "austenite" implies nothing, like mineralogical names in general, and hence is stable in itself. Our infant branch of science may well learn from its elder sister, which has tried and proved the advantage of this non-indicative naming.

In those cases in which a name has been used in more than one sense we advise the retention of one and the abandon-

ment of the others, having obtained the consent of the proposers of such names for their abandonment.

Many whose judgment we respect object to our including certain of the less used names, e. g. from i to n in our list, holding them either to be confusing or to be needless.

It is true that several names (hardenite, martensite, sorbite, etc.), have been used with various meanings, and hence confusingly, in spite of which most of them should be retained, each with a single sharp-cut definition, because they are so useful.

As regards the alleged needlessness of certain names it is for each writer to decide whether he does or does not need names with nice shades of meaning, such as osmondite and troosto-sorbite. Those who look only at the general outlines and not at the details have no right to forbid the workers in detail from having and using words fitting their work; nor have those whose needs are satisfied by the three primary colors a right to forbid painters, dyers, weavers, and others from naming the many shades with which they are concerned. Like the lexicographer we must serve the reader by explaining those words which he will meet, whether we individually use or condemn them. We feel that we have exhausted our powers in cautioning writers that certain words are rare and not likely to be understood by most readers, or are improper for any reason, and in urging the complete abandonment of those withdrawn by their proposers.

Needless words will die a natural death; needed ones we cannot kill. The good we might do in hastening the death of the moribund by omitting them from this report is less than the good we do by teaching their meaning to those who will meet them in ante-mortem print. These readers have rights. We serve no class, but the whole.

Illustrations. At the end of the several descriptions the reader is referred to good illustrations in Osmond and Stead's Microscopic Analysis of Metals, Griffin & Co., London, 1904.

II. List of Microscopic Substances.

The microscopic substances here described consist of

1. Metarals, true phases, like the minerals of nature. These are either elements, definite chemical compounds, or solid solutions

and hence consisting of definite substances in varying proportions. These include austenite, ferrite, cementite, and graphite.

2. **Aggregates**, like the petrographic entities as distinguished from the true minerals. These mixtures may be in definite proportions, i. e. eutectic, or eutectoid mixtures, (ledeburite, pearlite, steadite) or in indefinite proportions (troostite, sorbite). Those aggregates which are important for any reason are here described.

(Many true minerals, such as mica, felspar, and hornblende, are divisible into several different species so that these true mineral names may be either generic or specific. These genera and species are definite chemical compounds, in which one element may replace another. Other minerals, such as obsidian, are solid solutions in varying proportions, and in these also one element may replace another. Metarals like minerals differ from aggregates in being severally chemically homogeneous.)

These two classes may be cross classified into:

A) The iron-carbon series, which come into being in cooling and heating.

B) The important impurities, manganese sulphide, ferrous sulphide, slag, etc.

C) Other substances.

The most prominent members of the iron-carbon series are

I. molten iron, metaral, molten solution, but hardly a microscopic constituent.

II. the components which form in its solidification:

a) austenite, solid solution of carbon or iron carbide in iron, metaral;
b) cementite, definite metaral, Fe_3C;
c) graphite, definite metaral, C.

III. the transition substances which form through the transformation of austenite during cooling:

d) martensite, metaral of variable constitution; its nature is in dispute;
e) troostite, indefinite aggregate, uncoagulated mixture;
f) sorbite, indefinite aggregate, chiefly uncoagulated pearlite plus ferrite or cementite;

IV. products*) of the transformation of austenite:

*) In hypo-eutectoid steels these habitually play the part of end products, though according to the belief of most the true end of the transformation is not reached till the whole has changed into a conglomerate of ferrite plus graphite.

g) ferrite;

h) pearlite.

This transformation may also yield cementite and graphite as end products in addition to those under b and c.

In addition to the above, the names of which are universally recognized and in general use, the following names have been used more or less.

i) ledeburite (Wüst), definite aggregate, the austenite-cementite eutectic;

j) ferronite (Benedicks) hypothetical definite metaral, β iron containing about 0·27 per cent of carbon;

k) steadite, (Sauveur) definite aggregate, the iron-phosphorus eutectic (rare);

And three transition stages in the transformation of austenite, viz:

l) hardenite, (Arnold) collective name for the austenite and martensite of eutectoid composition;

m) osmondite, (Heyn) boundary stage between troostite and sorbite;

n) troosto-sorbite, (Kourbatoff) indefinite aggregate, the troostite and the sorbite which lie near the boundary which separates these two aggregates; (obsolescent).

III. Definitions and Descriptions.

Carbon iron equilibrium diagram, Fig. 1. Under the several substances about to be described an indication will be given of the parts of the carbon iron equilibrium diagram Fig. 1 to which they severally correspond.

Austenite, Osmond (Fr. Austénite, Ger. Austenit called also mixed crystals and gamma iron. Up to the year **1900** often called martensite, and wrongly sometimes still so called). Metaral of variable composition.

Definition. The iron-carbon solid solution as it exists above the transformation range or as preserved with but moderate transformation at lower temperatures, e. g. by rapid cooling, or by the presence of retarding elements, (Mn, Ni, etc.), as in 12% manganese steel and 25% nickel steel.

Constitution and Composition. A solid solution of carbon or iron carbide (probably Fe_3C) and gamma iron, normally stable

only above the line PSK of the carbon iron diagram. It may have any carbon content up to saturation as shown by the line SE viz.: — about 0·90% at S (about 725° C) to 1·7% at E (about 1130°). The theory that the iron and the carbide or carbon, instead of being dissolved in each other, are dissolved in

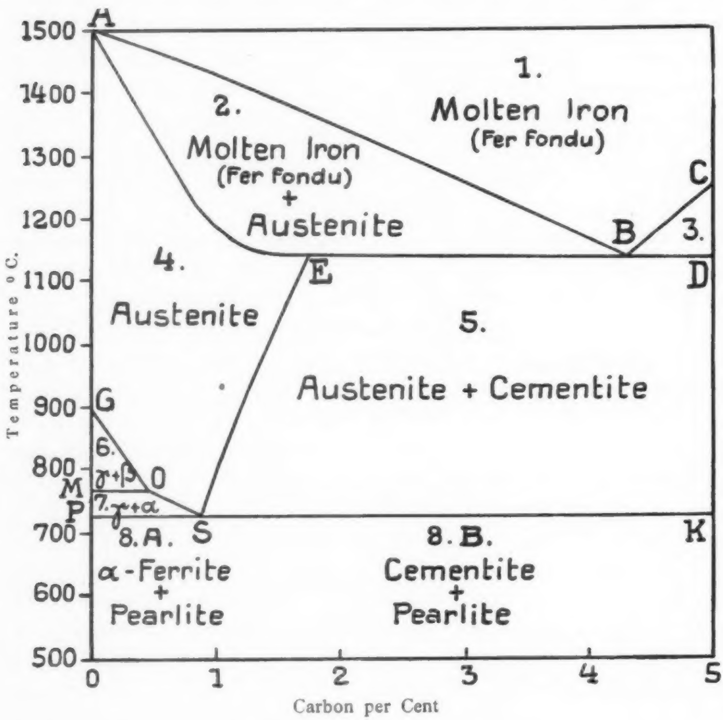


Fig. 1.

A1. The line PSK is often called "A1".

A3. The line GOS is often called "A3", and this name is sometimes applied to the line SE.

a third substance, the solution of eutectic composition (Fe_{24} C, called hardenite) is not in accord with the generally accepted theory of the constitution of solutions, and is not entertained widely or by any member of this committee.

Crystallization. Isometric. The idiomorphic vug crystals are octahedra much elongated by parallel growth. The etched sections

show much twinning. (Osmond and most authorities.) Le Chatelier believes it to be rhombohedral. Cleavage octahedral.

Varieties and genesis. 1. Primary austenite formed in the solidification of carbon steel and hypo-eutectic cast iron; 2. eutectic austenite, interstratified with eutectic cementite, making up the eutectic formed at the end of the solidification of steel containing more than about 1·7% of carbon, and of all cast iron.

Equilibrium. It is normal and in equilibrium in Region 4, and also associated with beta iron in Region 6, with α iron in Region 7, and with cementite in Region 5. It should normally transform into pearlite with either ferrite or cementite on cooling past A1 into Region 8.

Transformation. In cooling slowly through the transformation range, Ar3—ArI, austenite shifts its carbon content spontaneously through generating pro-eutectoid ferrite or cementite, to the eutectoid ratio, about 0·90%, and then transforms with increase of volume at ArI into pearlite, q. v., with which the ejected ferrite or cementite remains mixed. Rapid cooling and the presence of carbon, manganese, and nickel obstruct this transformation, 1. retarding it and 2. lowering the temperature at which it actually occurs, and in addition 3. manganese and nickel lower the temperature at which in equilibrium it is due. Hence by combining these four obstructing agents in proper proportions the transformation may be arrested at any of the intermediate stages, martensite, troostite, or sorbite*), q. v., and if arrested in an earlier stage, it can be brought to any later desired stage by a regulated reheating or "tempering". For instance, though a very rapid cooling in the absence of the three obstructing elements checks the transformation but little and only temporarily, yet if aided by the presence of a little carbon it arrests the transformation wholly in the martensite stage; and in the presence of about 1·50% of carbon such cooling retains about half the austenite so little altered that it is "considerably" softer than the usually darker needles of the surrounding martensite, with which it contrasts sharply. Again either a) about

*) Though the transformation can be arrested in such a way as to leave the whole of the steel in the condition of martensite, it is doubted by some whether it can be so arrested as to leave the whole of it in any of the other transition stages. Troostite and sorbite caused by such arrest are habitually mixed, troostite with martensite or sorbite or both, and sorbite with pearlite or troostite or both.

12% of manganese plus 1% of carbon, or b) 25% of nickel, lower and obstruct the transformation to such a degree that austenite persists in the cold apparently unaltered, even through a slow cooling. (Hadfield's manganese steel and 25% nickel steel, manganiferous and niccoliferous austenite respectively.)

Occurrence. When alone, (12% manganese and 25% nickel steel and Maurer's 2% carbon plus 2% manganese austenite) polyhedra, often coarse, much twinned at least in the presence of martensite, and readily developing slip bands. In hardened high-carbon steel it forms a ground mass pierced by zig-zag needles and lances of martensite.

Etching. All the common reagents darken it much more than cementite, less than troostite or sorbite, and usually less, though sometimes more than martensite, which is recognized by its zig-zag shape, and needle structure. With ferrite and pearlite it is never associated.

Physical properties. Maurer's austenite of 2% manganese plus 2% carbon is but little harder than soft iron, and 25% nickel steel and Hadfield's manganese steel are but moderately hard. Yet as usually preserved in hardened high carbon steel, the hardness of austenite does not fall very far short of that of the accompanying martensite, probably because partly transformed in cooling. (Osmond's words are that it is "considerably" softer than that martensite.)

Specific Magnetism very slight unless perhaps in intense fields. In Hadfield's manganese steel and 25% nickel steel, very ductile.

Illustrations. Microscopic Analysis of Metals, Figs. 20, 50, and 51, on pp. 39, 100, and 101.

Cementite (Sorby "intensely hard compound", Ger. Cementit, Fr. Cémentite, Arnold, crystallized normal carbide). Definite metaral.

Definition. Tri-ferrous carbide, Fe_3C. The name is extended by some writers so as to include tri-carbides in which part of the iron is replaced by manganese, or other elements. Such carbides may be called "manganiferous cementite", etc.

2. Occurrence. a) pearlitic. as a component of pearlite, q. v.; b) eutectic; c) primary or pro-eutectic; d) pro-eutectoid; e) that liberated by the splitting up of the eutectic or of pearlite; and f) uncoagulated in sorbite, troostite, and perhaps martensite. c), d), and e) are grouped together as "free" or "massive".

Primary cementite is generated in cooling through Region 3; eutectic cementite on cooling past the line EBD; pro-eutectoid cementite in cooling through Region 5; pearlitic cementite on cooling past the line PSK, or A1. Though the several varieties of cementite are generally held to be all metastable, tending to break up into graphite plus either austenite above A1 or ferrite below A1, yet they have a considerable and often great degree of persistence. The graphitizing tendency is completely checked in the cold, but increases with the temperature, and with the proportion of carbon and of silicon present, and is opposed by the presence of manganese.

3. Crystallization. Orthorhombic, in plates.

4. Structure. a) Pearlitic, in parallel unintersecting plates alternating with plates of ferrite; b) Eutectic, plates forming a network filled with a fine conglomerate of pearlite with or without pro-eutectoid cementite; c) Primary, in manganiferous white cast iron etc., in rhombohedral plates; d) In hyper-eutectoid steel, pro-eutectoid cementite forms primarily a network enclosing meshes of pearlite, through which cementite plates or spines sometimes shoot if the network is coarse; e) Cementite liberated from pearlite merges with any neighbouring cementite; f) The structure of uncoagulated cementite cannot be made out. On long heating the pro-eutectoid and pearlitic cementite spheroidize slowly, and neighbouring particles merge; g) In white irons rich in phosphorus in flat plates embedded in iron-carbon-phosphorus eutectic.

5. Etching etc. After polishing stands in relief. Brilliant white after etching with dilute hydrochloric or picric acid; darkened by boiling with solution of sodium picrate in excess of sodium hydrate.

6. Physical properties. Hardest component of steel. Hardness = 6 of Mohs scale. Scratches glass and felspar but not quartz; very brittle. Specific magnetism about two-thirds that of pure iron.

Illustrations, Microscopic Analysis of Metals, Figs. 42, and 43 on pp. 84, 85.

Martensite (Fr. Martensite, Ger. Martensit), Metaral. Its nature is in dispute.

Definition. The early stage in the transformation of austenite characterized by needle structure and great hardness, as in hardened high-carbon steel.

Constitution. 1. (Osmond and others), a solid solution like austenite, q. v., except that the iron is partly beta, whence its

hardness, and partly alpha, whence its magnetism in mild fields. II. (Le Chatelier) the same except that its iron is essentially alpha, and the hardness due to the state of solid solution. III. (Arnold) a special structural condition of his "hardenite" (austenite); not widely held. IV. A solid solution in gamma iron. V. (Benedicks.) The same as I, except that the iron is wholly beta, and that beta iron consists of alpha iron containing a definite quantity of gamma iron in solution.

Equilibrium. It is not in equilibrium in any part of the diagram, but represents a metastable condition in which the metal is caught during rapid cooling, in transit between the austenite condition stable above the line AI and the condition of ferrite plus cementite into which the steel habitually passes on cooling slowly past the line AI.

Occurrence. The chief constituent of hardened carbon tool steels, and of medium nickel- and manganese-steels. In still less fully transformed steels (1·50% carbon steel rapidly quenched, etc.) it is associated with austenite; in more fully transformed ones (lower carbon steels hardened, high carbon steels oil hardened, or water hardened and slightly tempered, or hardened thick pieces even of highcarbon steel) it is associated with troostite, and with some pro-eutectoid ferrite or cementite, q. v., in hypo- and hyper-eutectoid steels respectively. In tempering it first changes into troostite; at 350°—400° it passes through the stage of osmondite; at higher temperatures it changes into sorbite; and at 700° into granular pearlite. On heating into the transformation range this changes into austenite, which on cooling again yields lamellar pearlite.

Characteristic specimens are had by quenching bars 1 cm square of eutectoid steel, i. e. steel containing about 0·9% of carbon in cold water from 800° C (1472° F).

Structure. When alone, habitually in flat plates made up of intersecting needles parallel to the sides of a triangle. When mixed with austenite, zig-zag needles, lances, and shafts.

If produced by quenching after heating to 735° C, it consists of minute crystallites resembling the globulites of Vogelsang, which are rarely arranged in triangular order. At times so fine as to suggest being amorphous.

Etching. With picric acid, iodine, or very dilute nitric acid etches usually darker than austenite, but sometimes lighter, always darker than ferrite and cementite, but always lighter than troostite.

Illustrations, Microscopic Analysis of Metals, Figs. 19, p. 38, Fig. 52 on p. 102.

Ferrite (Fr. Ferrite, Ger. Ferrit), definite metaral.

1. Definition. Free alpha-iron.

2. Composition. Nearly pure iron. It may contain a little phosphorus and silicon, but its carbon content if any is always small, at the most not more than 0·05%, and perhaps never as much as 0·02%,

3. Occurrence. (a), pearlitic as a component of pearlite, q. v.; (b), pro-eutectoid ferrite generated in slow cooling through the transformation range; (c) that segregated from pearlite, i. e set free by the splitting up of pearlite, especially in low carbon steel; (d) uncoagulated as in sorbite, and probably troostite. (b) and (c) are classsed together as free or massive.

Thus ferrite is normal and stable in regions 7 and 8.

4. Crystallisation, isometric, in cubes or octahedra.

5. Structure. (a) pearlitic ferrite, unintersecting parallel plates alternating with plates of cementite; (b) pro-eutectoid ferrite in low-carbon steel forms irregular polygons, each with uniform internal orientation. In higher carbon steel, after moderately slow cooling, especially in the presence of manganese, it forms a network enclosing meshes of pearlite. In slower cooling this network is replaced by irregular grains separated by pearlite; (c) the ferrite set free by the splitting up of pearlite merges with the pro-eutectoid ferrite if any; (d) the structure of the ferrite in sorbite etc. cannot be made out.

6. Etching. Dilute alcoholic nitric or picric acid on light etching leaves the ferrite grains white with junctions which look dark. Deeper etching, by Heyn's reagent or its equivalent, reveals the different orientation of the crystals or grains, (a) as square figures parallel to the direction of the etched surface, (b) as plates which dip at varying angles and become dark or bright when the specimen is rotated under oblique illumination. Still deeper etching reveals the component cubes, (etching figures, Ätzfiguren), at least if the surface is nearly parallel to the cube faces.

7. Physical Properties. Soft; relatively weak (tenacity about **40,000** lbs. per sq. in.); very ductile; strongly ferro-magnetic; coercitive force very small.

Grain Size. For important purposes (1) etch deeply enough, e. g. with copper-ammonium chloride, to reveal clearly the junctions of the grains; (2) count on a photograph of small magnification the number of grains in a measured field so drawn as to exclude fragments of grains; after (3) determining the true grain boundaries by examination under high powers (Heyn's method). Deep nitric acid etching is inaccurate, because an apparent grain boundary may contain several grains.

Illustrations, Microscopic Analysis of Metals, Figs. **41**, **56**, pp. **79**, **116**.

Osmondite (Fr. Osmondite, Ger. Osmondit).

Definition. That stage in the transformation of austenite at which the solubility in dilute sulphuric acid reaches its maximum rapidity. Arbitrarily taken as the boundary between troostite and sorbite.

Earlier Definition. Defined by the V[th.] Congress as having the "maximum solubility in acids and by a maximum coloration under the action of acid metallographic reagents". The present definition is confined to maximum rapidity of dissolving, because we do not yet know that this in all cases co-exists with the maximum depth of coloration, and in any case in which these two should not co-exist, the old definition does not decide which is true osmondite.

Constitution. The following hypotheses have been suggested, none of which has firm experimental foundation. 1. A solid solution of carbon or an iron carbide in alpha iron. 2. The colloidal system of Benedicks in its purity, troostite being this system while forming at the expense of martensite, and sorbite, being this system coagulating and passing into pearlite. 3. The stage of maximum purity of amorphous alpha iron on the way to crystallising into ferrite.

Occurrence. Hardened carbon steel of about 1% of carbon when reheated (tempered) to **350—400°** C passes through the stage of troostite to that of osmondite, and on higher heating to that of sorbite. What variation if any from this temperature is needed

to bring hardened steel of other carbon content to the osmondite stage is not known. In that it represents a true boundary state between troostite and sorbite it differs in meaning from troosto-sorbite which embraces both the troostite and the sorbite which lie near this boundary. Indeed osmondite has sometimes been used in this looser sense. Writers are cautioned that, however useful these terms may prove for making these nice discriminations, they are not likely to be familiar to general readers.

Etching. According to Heyn it differs from troostite and sorbite in being that stage in tempering which colors darkest on etching with alcoholic hydrochloric acid.

The present definition and description of osmondite should displace previous ones, because they have the express approval of Professor Heyn, the proposer of the name, and M. Osmond himself.

Ferronite (Fr. Ferronite, Ger. Ferronit) (Benedicks) hypothetical definite metaral.

Definition. Solid solution of about $0{\cdot}27\%$ of carbon in beta iron.

Occurence, (hypothetical). In slowly cooled steels and cast iron containing $0{\cdot}50\%$ of combined carbon or more, that which is generally believed to be ferrite, whether pearlitic or free, is supposed by Benedicks to be ferronite.

Hardenite (Fr. Hardenite, Ger. Hardenit).

Definition. Collective name for austenite and martensite of eutectoid composition. It includes such steel (1) when above the transformation range, and (2) when hardened by rapid cooling.

Observations. On the generally accepted theory that austenite is a solid solution of carbon or an iron carbide in iron, hardenite is the solution of the lowest transformation temperature, i. e. the eutectoid. The theory that instead it is a definite chemical compound, $Fe_{24}C$, is considered under Austenite. Its proposer includes under hardenite both eutectoid ($0{\cdot}90\%$ carbon) austenite when above the transformation range, and the martensite into which that austenite shifts in rapid cooling (hardening).

Other Meanings. Originally (Howe, 1888) collective name for austenite and martensite of any composition in carbon steel. Osmond (1897), austenite saturated with carbon. Both these meanings are withdrawn by their proposers.

Pearlite (Sorby's "pearly constituent". At first written "pearlyte" Fr. Perlite, Ger. Perlit) Aggregate.

Definition. The iron-carbon eutectoid, consisting of alternate masses of ferrite and cementite.

Constitution and Composition. A conglomerate of about **6** parts of ferrite to 1 of cementite. When pure, contains about **0·90%** of carbon, **99·10%** of iron.

Occurrence. Results from the completion of the transformation of austenite brought spontaneously to the eutectoid carbon-content, and hence occurs in all carbon steels and cast iron containing combined carbon and cooled slowly through the transformation range, or held at temperatures in or but slightly below that range, long enough to enable the ferrite and cementite to coagulate into a mass microscopically resoluble. Hence it is the normal constituent in Region 8. Its ferrite is stable but its cementite is metastable and tends to transform into ferrite and graphite.

Varieties and Structure. Because pearlite is formed by the coagulation of the ferrite and cementite initially formed as the irresoluble emulsion, sorbite, (Arnold's sorbitic pearlite) there are the indefinitely bounded stages of sorbitic pearlite, (Arnold's normal pearlite), i. e. barely resoluble pearlite, in the border land between sorbite and laminated pearlite; granular pearlite, in which the cementite forms fine globules in a matrix of ferrite; and laminated or lamellar pearlite, consisting of fine, clearly defined, non-intersecting, parallel lamellae alternately of ferrite and cementite. The name granular pearlite was first used by Sauveur to represent what is now called sorbite. This meaning has been withdrawn.

An objection to Arnold's name "normal pearlite" is that it is likely to mislead. "Normal" here apparently refers to arising under normal conditions of cooling, but (1) it rather suggests structure normal for pearlite, which surely is the lamination characteristic of eutectics in general, and (2) the general reader has no clue as to what conditions of cooling are here called normal. Many readers are not manufacturers, and even in manufacture itself air cooling is normal for one branch and extremely slow furnace cooling for another. Arnold calls troostite "troostitic pearlite" and sorbite „sorbitic pearlite". This is contrary to general usage, which restricts pearlite to microscopically resoluble masses.

Etching. After etching with dilute alcoholic nitric or picric acid it is darker than ferrite or cementite but lighter than sorbite and troostite. A magnification of at least 250 diameters is usually needed for resolving it into its lamellae, though the pearlite of blister steel can often be resolved with a magnification of 25 diameters. The more rapidly pearlite is formed, the higher the magnification needed for resolving it.

Illustrations, lamellar pearlite. Osmond and Stead, Microscopic Analysis, Fig. 11, p. 19, Granular pearlite, idem Fig. 18, p. 36; Heyn and Bauer, Stahl und Eisen 1906, Fig. 14, opposite p. 785.

Graphite (Ger. Graphit, Fr., Graphite), definite metaral.

Definition. The free elemental carbon which occurs in iron and steel.

Composition. Probably pure carbon, identical with native graphite.

Genesis. Derived in large part, and according to Goerens wholly, from the decomposition of solid cementite. Others hold that its formation as kish may be from solution in the molten metal, and that part of the formation of temper graphite may be from elemental carbon dissolved in austenite. It is the stable form of carbon in all parts of the diagram.

Occurrence. 1. as kish, flakes which rise to the surface of molten cast iron and usually escape thence;

2. as thin plates, usually curved, e. g. in gray cast iron, representing carbon which has separated during great mobility, i. e. near the melting range;

3. as temper graphite (Ger. Temperkohle, Ledebur) pulverulent carbon which separates from cementite and austenite, especially in the annealing process for making malleablized castings.

Graphite and ferrite are sometimes associated in a way which suggests strongly that they represent a graphite-austenite eutectic. But the existence of such a true eutectic is doubted by most writers.

Properties. Hexagonal H. 1—2. Gr. 2·255. Streak black and shining, lustre metallic; macroscopic color, iron black to dark steel gray, but always black when seen in polished sections of iron or steel under the microscope; opaque; sectile; soils paper; flexible; feel, greasy.

Troostite (Fr. Troostite, Ger. Troostit). Probably aggregate. (Arnold, troostitic pearlite).

Definition. In the transformation of austenite, the stage following martensite and preceding sorbite (and osmondite if this stage is recognized).

Constitution and composition. An uncoagulated conglomerate of the transition stages. The degree of completeness of the transformation represented by it is not definitely known and probably varies widely. Osmond and most others believe that the transformation, while generally far advanced, yet falls materially short of completion; but Benedicks and Arnold (9) believe that it is complete. The former belief that it is a definite phase, e. g. a solid solution of carbon or an iron carbide in either β or γ iron, is abandoned. Its carbon-content like that of austenite and martensite varies widely.

Occurrence. It arises either on reheating hardened (e. g. martensitic steel) to slightly below **400°**, or on cooling through the transformation range at an intermediate rate, e. g. in small pieces of steel when quenched in oil, or quenched in water from the middle of the transformation range, or in the middle of larger pieces quenched in water from above the transformation range. With slightly farther reheating it changes into sorbite; with higher heating into sorbitic pearlite, then slowly into granular pearlite, and probably indirectly into lamellar pearlite. It occurs in irregular, fine-granular or almost amorphous areas, colored darker by the common etching reagents than the martensite or sorbite accompanying it. A further common means of distinguishing it from sorbite is that it is habitually associated with martensite, whereas sorbite is habitually associated with pearlite.

Areas near the boundary between troostite and sorbite are sometimes called troosto-sorbite.

Properties. Hardness, intermediate between that of the martensitic and the pearlitic state corresponding to the carbon content of the specimen. In general the hardness increases, the elastic limit rises, and the ductility decreases, as the carbon-content increases. Its ductility is increased rapidly and its hardness and elastic limit lowered rapidly by further tempering, which affects it much more markedly than sorbite.

Sorbite (Fr. Sorbite, Ger. Sorbit). Aggregate. (Arnold, sorbitic pearlite.)

Definition. In the transformation of austenite, the stage following troostite and osmondite, if this stage is recognized, and preceding pearlite.

Constitution and Composition. Most writers believe that it is essentially an uncoagulated conglomerate of irresoluble pearlite with ferrite in hypo- and cementite in hyper-eutectoid steels respectively, but that it often contains some incompletely transformed matter.

Occurrence. The transformation can be brought to the sorbitic stage (1) by reheating hardened steel to a little above 400°, but not to 700° at which temperature it coagulates into granular pearlite; (2) by quenching small pieces of steel in oil or molten lead or even by air-cooling them; (3) by quenching in water from just above the bottom of the transformation range, Ar_1 Sorbite is ill-defined, almost amorphous, and is colored lighter than troostite but darker than pearlite by the usual etching reagents. It differs further from troostite in being softer for given carbon content, and usually in being associated with pearlite instead of martensite, and from pearlite in being irresoluble into separate particles of ferrite and cementite.

As sorbite is essentially a mode of aggregation it cannot properly be represented on the equilibrium diagram. Its components at all times tend to coagulate into pearlite, yet it remains in its uncoagulated state at all temperatures below 400°.

Properties. Though slightly less ductile than pearlitic steel for given carbon content, its tenacity and elastic limit are so high that a higher combination of these three properties can be had in sorbitic than in pearlitic steels by selecting a carbon content slightly lower than would be used for a pearlitic steel. Hence the use of sorbitic steels, e. g. first hardened and then annealed cautiously, for structural purposes needing the best quality.

Manganese Sulphide (Fr. Sulphure de Manganèse, Ger. Schwefelmangan), MnS, (Arnold and Waterhouse). Metaral.

Occurrence etc. Sulphur combines with the manganese present in preference to the iron, forming pale dove or slate gray masses, rounded in castings, elongated in forgings.

Ferrous Sulphide (Fr. Sulphure de Fer, Ger. Schwefeleisen), FeS. Metaral.

Occurrence. The sulphur not taken up by the manganese forms ferrous sulphide, FeS, which, probably associated in part with iron as an Fe—FeS eutectic, forms by preference more or less continuous membranes surrounding the grains of pearlite. Color, yellow, or pale brown.

Sulphur Prints. When silk impregnated with mercuric chloride and hydrochloric acid (Heyn's and Bauer's method) or bromide paper moistened with sulphuric acid (Baumann's method) is pressed on polished steel, the position of the sulphur-bearing areas, whether of FeS or MnS, records itself by the local blackening which the evolved H_2S causes. Phosphorus bearing areas also blacken Baumann's bromide paper.

Miscellaneous.

Eutectoid, Saturated, etc. The iron carbon eutectoid is pearlite. Steel with more carbon than pearlite is called hyper-eutectoid, that with less is called hypo-eutectoid. Arnold's names "saturated", "unsaturated", and "supersaturated", for eutectoid, hypo-eutectoid, and hyper-eutectoid steel respectively, have considerable industrial use in English speaking countries, but are avoided by most scientific writers on the ground that they are misleading, because, e. g. there is only one specific temperature, Al, at which eutectoid steel is actually saturated, and, if any other temperature is in mind, that steel is not saturated. Above Al it is clearly under-saturated.

The objection to the names sorbite, troostite, martensite, and austenite, that each of them covers steel of a wide range of carbon content, is to be dismissed because a like objection applies with equal force to every generic name in existence.

The theoretical matter in this report is given solely for exposition and the committee disclaims the intent to impose any theory. This report is offered for adoption subject to this disclaimer on the ground that the adoption of theories is beyond the powers of a Congress.

REPRINTED BY PERMISSION FROM THE "PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS".

MICROGRAPHICAL STUDIES.

MEMOIR

on certain Micrographical Observations of practical Interest for Valuing and Testing and for Working Metals by different Methods.

By the **Atelier des Essais de Métaux de la Cie. des Chemins de Fer P. L. M.**

(Translated from the French by H. Borns.)

1. Rapid Estimation of Arsenic in Red Copper.

We have been investigating, whether it would be possible to determine, with technical accuracy, the contents of arsenic in fire box plates of arseniferous copper by micrographical observations, instead of by chemical analysis.

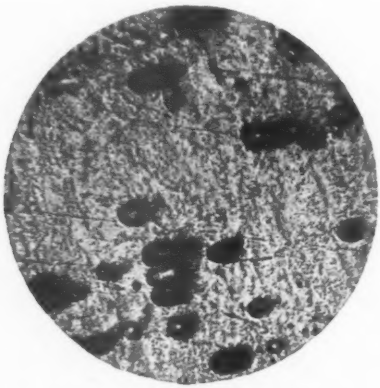
When a specimen of arsenious copper, previously polished, is etched with pure nitric acid at 22° for 5 or 6 seconds, the microscopical examination will display more or less abundant and voluminous black spots, according to the percentage of arsenic present.

With an enlargement of 200 diameters these spots assume the form of grains of flour, showing in the centre a brilliant spot with extremely fine needles (microphotograph No. 1—A, 200 diameters).

We have prepared a scale of six standard specimens containing, as the analysis established, 0, 0·35, 0·40, 0·45, 0·50, 0·55% of arsenic (microphotographs No. 2—A to No. 7—A, all enlarged 200 diameters).

By comparing any specimen with the above photographs one can, with a little experience, determine the percentage of arsenic within approximately 0·06%.

Examining 86 specimens in this way by comparison with our scale and subsequently analysing the same by the usual chemical methods, we have obtained concordant results in 63 cases. The remaining 23 specimens showed discrepancies amounting to 0·11%; but the check analysis likewise displayed discrepancies of 0·08%, which would prove that in these instances the arsenic was very unevenly distributed through the metal.



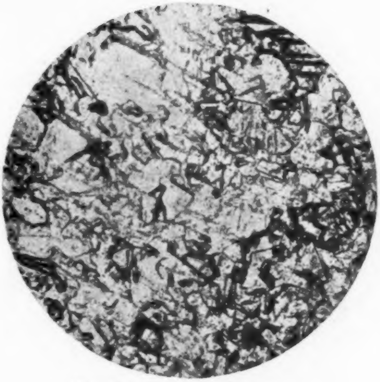
No. 1—A. Enlargement: 200 diameters.

It is further noteworthy that the crystallisation of the copper which was very marked in the pure copper (photograph No. 2—A) onsiderably diminished as soon as arsenic enters into the metal. When the arsenic contents reach or exceed 0·45%, the tendency to crystallisation disappears entirely.

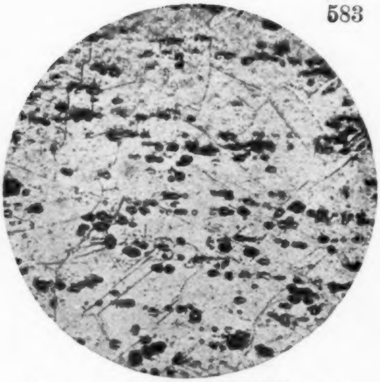
2. Carburising produced on the Edge of Steel Plates or of Forged Plates by cutting them with the Oxy-Acetylene Blowpipe.

The use of the oxy-acetylene blowpipe for cutting steel plates is spreading more and more, and we have investigated the width of the zone of carbonisation which is produced by this method of cutting.

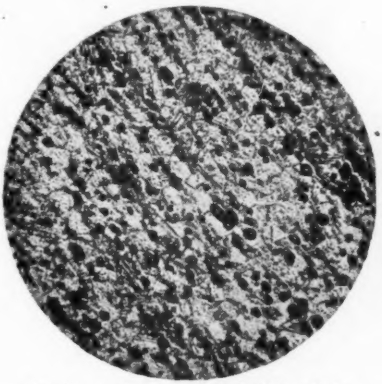
When photographing a steel bar, 28 mm in thickness, containing 0·12% of carbon, which had been cut in this way, we ascertained that the zone of alteration differed at different points



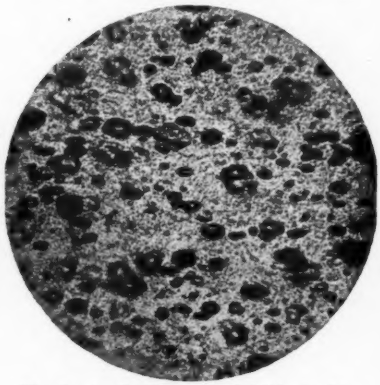
No. 2—A. Pure Copper.



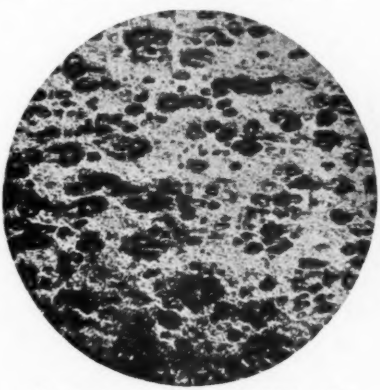
No. 3—A Copper with 0 35% of As.



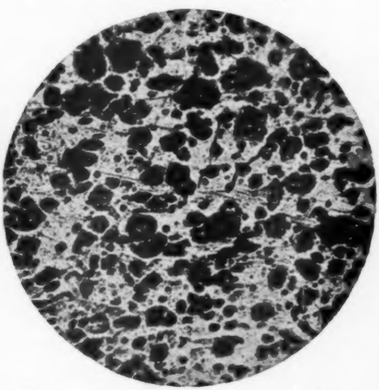
No 4—A. Copper with 0 40% of As.



No. 5—A. Copper with 0·45% of As.



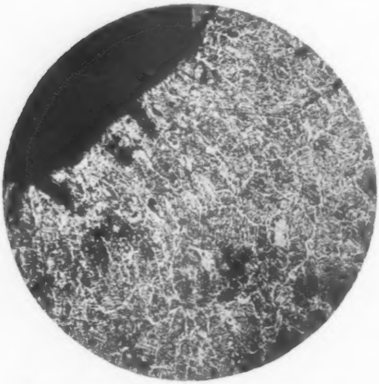
No. 6—A. Copper with 0·50% of As.



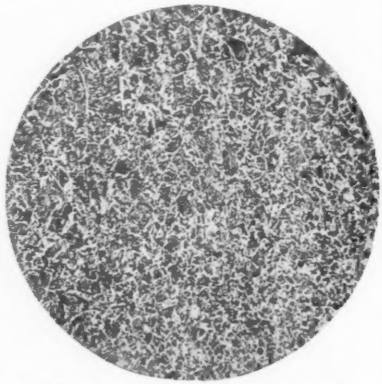
No. 7—A. Copper with 0·55% of As.

ranging from 0·5 up to 5 mm as the microphotographs No. 1—B, 2—B, 3—B, (magnification 30 diameters) exemplify.

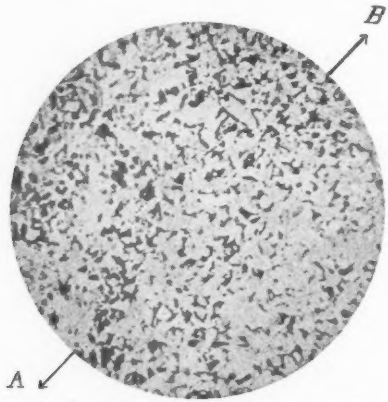
The first Photograph (No. 1—B) shews the edge cut by the jet; we notice the black zone on the left side at the top.



No. 1—B. Magnification: 50 diameters.



No. 2—B. Magnification: 50 diameters.



No. 3—B. Magnification: 50 diameters.

The second Photograph (No. 2—B), taken 0·5 mm from the edge, shews the zone of a carburised metal containing about 0·45% of carbon.

The third Photograph (No. 3—B), taken 5 mm from the edge, marks the limit of the carburised zone (line A B); the metal remains unaltered almost throughout.

We have thus felt justified to permit the application of this method of cutting by the blowpipe in full security for locomotiva frame plates; but we have insisted that the builder should keep a zone of 10 mm width between the edge of the seam made by the blow pipe and the final trace, so as to make sure that all the affected metal should be removed by the machine tool.

We have moreover been able to convince ourselves that this precaution is sufficient. We have submitted steel bars prepared under these conditions to bending tests on edge. The locomotives which were provided with frame plates, cut in this way, have for some time been doing duty, and no trouble has arisen from this cause.

3. Effects of Cold Work due to the Threading Screws of Large Diameters.

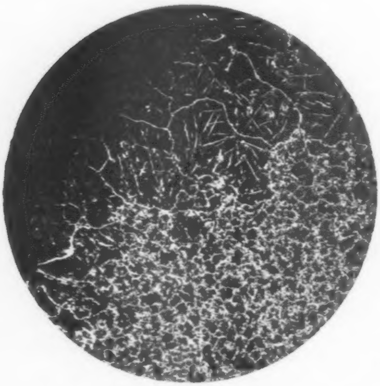
A certain number of screws for coupling bars made of soft steel of a strength of about 40 kg broke, while in service or when under acceptance tests, sudden a with a small elongation and almost without contraction of area; the fracture was sharp and fine-grained. In cutting off a section of a screw which had not yet been tested we found by the Brinell ball-test (at that moment we did not yet possess a microscope), that the metal was much harder in the neighbourhood of the thread than in the middle. The effect of the work semed to have penetrated, so far as we could approximately estimate, to a depth of 3 or 4 mm.

We have hence made it a rule in our specifications that all coupling screws should be annealed again at about 700° after threading.

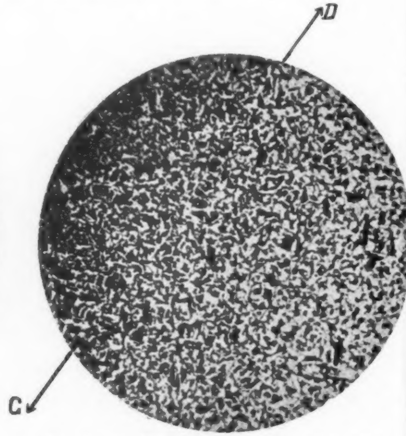
Since then we have, in all our breaking tests, observed considerable contraction of area and elongation without appreciable loss in the load. In this way the work done in rupture has very considerably been raised. This work, it is well known, is equal to the area of a curve whose abscissae represent the stress and whose ordinates mark the corresponding elongation.

The same fact, i. e. sudden rupture without striction, having been observed with other screws, which were threaded to the same diameter and pitch, we have again prepared a section and, having polished the metal and etched it with picric acid, we have

been able exactly to determine the width of the strained zone which in these cases amounted to 3 mm. In this zone the ferrite appeared crushed and dissaminated in fine needles. The strained zone disappeared completely after annealing at 700° C.



No. 1—C. Magnification: 50 diameters.



No. 2 – C. Magnification: 50 diameters.

No. 3—C. Magnification: 50 diameters.

Microphotograph No. 1—C. Hard zone in the neighbourhood of the thread.

Microphotograph No. 2—C. Shewing the extension of the worked zone (on the right at the top) and the normal metal (line CD).

It is noteworthy that we have been able to obtain the same needles in submitting a piece of steel to work by pressure in the cold (microphotograph No. 3—C).

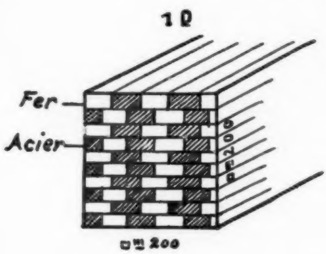
4. How to recognise Adulteration of Wrought Iron by the Insertion of Rolled Cast Steel in the Fagots.

Several mishaps having occurred in preparing forgings of iron of a strength superior or equal to 37 kg/mm^2, a want of weldability being particularly noticeable, we examined these irons microscopically after having polished the specimens and etched them with picric acid.

We then discovered bands which were plainly pearlitic, suggesting the presence of a kind of steel; the carbon contents reached 0·25%, corresponding to a strength of 55 kg/mm^2 (microphotograph No. 1—D).

In certain irons the steel-like portions came off plainly in strips, and we were thus led to suppose that certain mills, in order to increase the strength of the iron, added to their puddle iron some cast steel of rather high carbon percentage. One of the mills readily admitted that they had resorted to this practice. We therefore proceeded synthetically and piled up a fagot of bars of fibrous puddle iron and of cast steel bars of a strength of about 55 kg/mm^2 (see sketch No. 1—D).

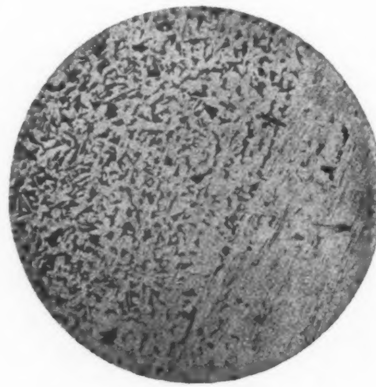
Having rolled rods of 35 mm we found that the resulting metal had a tensile strength of 37 kg and an elongation of 31·7%; it appeared to weld well, but in reality no welding was produced, and the parts separated in the joint under alternating torsion.



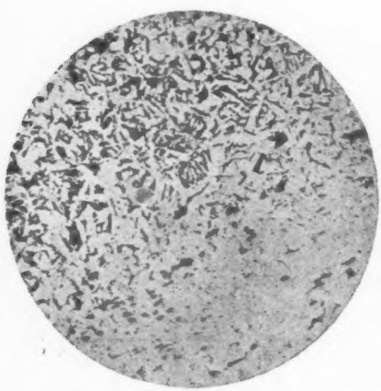
We then made an analagous pile, out of 68% of puddle iron and 32% of a steel-like iron, also puddled, and of a carbon percentage ranging from 0·15 to 0·30. Rolled to rods of 34 mm this product showed a tensile strength of 39 kg with an elongation of 30·8%. This metal welded easily, and it did not split in the joint under alternating torsion stress.

The presence in iron of layers of steel may, therefore, have different consequences for the future use of the metal; it depends

No. 1—D. Fagotting Iron with Steel; magnification: 50 diameters.



No. 2—D. Fagotting Round Iron with Steel by piling up cast steel and soft puddle iron; magnification: 50 diameters.



No. 3—D. Fagotting Round Iron with Steel by piling up cast steel and soft puddle iron; magnification: 50 diameters.

No. 4—D. Swedish Iron free of Steel Components; magnification: 50 diameters.

upon the character of the added steel, whether it be cast steel or puddle steel.

We have hence attempted to investigate, whether we could micrographically differentiate between bars made under addition of cast steel and bars containing puddle steel.

There did not at first appear to be any hope of effecting this distinction. For we had previously observed on sections, that the puddlesteel did not micrographically differ from the cast steel. Longitudinal sections have, however, shown to us, that the penetration of the pearlite of puddled steel into the iron was very intimate, and that it spread deeply without leaving any distinct traces of separation, whilst with the cast steel the delimitation was of a very characteristic distinctness.

As it appeared little to the practical purpose, however, to apply the micrographical control method to a lot of bars of some value, because it is a laboratory test, we have advised our material department, no longer to make use of high-strength iron for any parts which may have been made or may have to be repaired by welding. For such parts we recommend the use of iron which does not exceed a strength of 34 kg/mm^2 and which only contains carbon in feeble traces that are well disseminated. Such iron can easily be produced without introducing any cast steel or puddle steel into the fagots.

Although we do not advocate a micrographical test, it should nevertheless be remembered, that it was micrographical studies which have led us to adopt this precaution.

These various researches have been conducted under the direction of Mr. Vanderheym, Engineer in charge of the service, by Mr. Belanger, Assistant Engineer, and Mr. Charlemagne, Controller of the testing shops.

Summary

1. Rapid estimation of arsenic in red copper-after etching the polished metal with nitric acid black spots make their appearance, and the abundance of these spots bears a direct relation to the arsenic contents.

2. When sheet metal is cut by means of the oxy-acetylene blow piper, a zone of higher carburisation is produced near the edge of the cutting.

3. Determination of the stratum of worked metal produced by screw-cutting. The ferrite appears crushed and disseminated in fine needles.

4. Recognition of te introduction of strips of cast steel in fagots of iron. The pearlitic zones are much better defined and more marked than when puddle steel has been introduced.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

NOTES ON THE BRITTLENESS TEST.

By **M. Derihon**.

Assistant Manager, Usines G. Derihon, Liège (Belgium) and Jeumont (France).
(Translated by C. Salter.)

As a matter of probable interest we communicate a number of observations collected in the course of our experience since we began to make use of the brittleness test as a standard method for our steels and forgings.

Since 1904 we have used the drop weight and Frémont test piece for our tests, and we may state at once that our experience of both has been such that we have decided not to abandon them.

We may say that our laboratory, though complete enough so far as mechanical tests are concerned, is not a scientific laboratory but serves as a guide in close relation with the manufacturing department.

At present, apart from the chemical analyses, tensile tests, ball tests, etc., we have to apply the brittleness test to 80—100 tons of steel per month, bar by bar; and if we add that we leave a test piece for the brittleness test on each article of a certain class of goods that we produce, such as steering swivels and steering levers for motor cars, it will be easily imagined that we have to test about 10—12000 pieces every month.

It will be evident that in this way we have acquired a certain experience in this kind of test, and have been enabled to form certain conclusions of a practical character.

In the first place, is the brittleness test as stringent and misleading as is generally believed?

No, on the contrary we belive that after a few attempts it is possible to make all steels of good medium quality non-brittle.

The whole question is merely a matter of heat treatment.

Evidently, steels burdened with sulphur and phosphorus, or rotten with piping, will always remain brittle whatever one may do; but a good ordinary steel, properly treated, is nearly always non-brittle.

At the commencement of our tests, as at present, we used, in addition to certain fine, high-grade steels, a large number of open-hearth steels of various grades, the quality of which always remained approximately the same.

Well, at the outset we had to reject for brittleness, 20, 30 and even 40% of the pieces tested, whereas, at the present time we find that the total number of rejections in 1911 did not exceed an average of 3 per 1000.

This results entirely from the progress which these tests have enabled us to make in the application of heat treatment to our steel forgings. Our deduction therefore is that the brittleness test has done us good service by affording us the means of arriving at such homogeneous results.

Finally, can it be said that a test which gives rise to only 0·3% of rejections is incapable of being employed in practice?

Evidently one must become familiar with the impact test, and not attach undue importance to variations caused in toto by the heterogeneity of the metal.

A certain grade of steel must be classed as brittle when, for instance, the resilience is shown by the test to be less than 20 kilogrammetres, and as not so when the results are more favourable; but one must not seek to grade the quality in accordance with the values obtained.

In our opinion, it is the search after this precision which has led to the large test-piece being selected at the expense of the small one.

The former, of much greater sectional area, evidently gives mean results which are more easily comparable and apparently more rational; but it is attended with the defect of being incapable of showing up the weaknesses of the material, which are pitilessly exposed by the small test-piece assisted by macrography.

Being desirous of settling the point we selected 6 bars from a parcel of steel which had been rejected in consequence of the tests on Frémont test pieces, and from each bar prepared two

30 by 30 mm. test pieces of the Copenhagen type, with which we obtained the following results in the Charpy apparatus:

Bar Nr. 1	75	kilogrammetres and	75	kilogrammetres
„ „ 2	23	„ „	25	„
„ „ 3	7·5	„ „	8	„
„ „ 4	23	„ „	20·5	„
„ „ 5	41·7	„ „	41·7	„
„ „ 6	75	„ „	75	„

If these bars were to be rejected on account of giving values below 20 kilogrammetres, then only the bar No. 3 would be thrown out, and perhaps Nr. 4 as well. However, they were al bad since, independently of the Frèmont test, which had condemned them, macrographical examination revealed the presence of serious pipings.

Hence, we do not think it rash to conclude that, without the Frémont test, we should have been led to employ steels of bad quality.

The large test-piece is evidently not always optimistic, and reveals certain causes of brittleness; but in our opinion, it does not always expose them and with the same rigour as the small test piece.

But since the causes of brittleness in steel are often local, it would seem preferable to isolate them rather than conceal them in the mass of the metal.

So far as concerns ourselves, one serious reproach we address to the 30 by 30 mm. test piece is that it cannot be used in the case of the forgings we produce, owing to its large size.

We are well aware that the Copenhagen Congress recommends in such cases the use of the 10 by 10 mm. test piece, nicked half way through; but we must confess we should have preferred to keep to the Frémont type of test piece, 10 by 8 mm with a 1 mm nick.

In the first place, being flat, this test piece presents the advantage of enabling the direction of the fibres of the metal to be traced. It is also less expensive and less difficult, the small hole terminating the nick of the 10 by 10 mm test piece being difficult to make readily; and we are acquainted with several laboratories in which the use of this nick has been abandoned on account of the difficulties experienced in the shop.

As for the sharp edges of the nick, we must confess that we have never troubled about them. On no occasion, in the large number of tests performed, have we found any of the unfavourable results to be due to the nick. When a test piece breaks under a low strain, it is because the steel is brittle; and since we have now only 0·3% of rejections, we think these minor points may be neglected.

Finally, although we have no desire to reopen the discussion as to which apparatus should be used for the impact test, we take the liberty of expressing our opinion, which is based, not on scientific considerations, but on personal experience of forging and stamping machines.

Frémont claims that his drop weight, or similar appliance, is alone capable of revealing brittleness in all cases. In our opinion he is right, and for the following reason.

We believe in the drop weight, because our forgings are made under the steam hammer and drop hammer; and we find that the velocity of the impact and the quantity of the mass receiving the impact are of prime importance.

The importance of these two factors is such that it is they which practically limit the work of our drop hammers.

The matrices, being made of very hard, and more or less brittle steel, will not stand, but are constantly breaking, if the height of fall be too great or the impact is too sharp. On this account we have therefore been compelled to reduce the height of fall, increasing the weight of the falling mass, and arranging under the anvil bed a foundation of wooden baulks. so as to take up the impact elastically.

This, however, is accomplished at the expense of the useful effect, since a weight of 500 kilos. falling from a height of 4 metres, is more economical than one of 1000 kilos. falling a height of 2 metres.

We belive therefore, as Frémont has said. that an apparatus which does not give sufficient velocity of impact or in which the anvil bed is not sufficiently heavy, cannot reveal the brittleness of the test metal in all cases.

The conclusion we draw from this is that, as was wisely decided by the Copenhagen Congress, the Congress should abstain from prescribing any special type of apparatus for performing the

impact test; but that it should direct attention to the importance, with regard to the results, of the velocity of the impact and the mass of the anvil bed receiving same.

Summary.

The author has adopted the brittleness test as the general test used in passing material at his works. His experience leads him to maintain that this test is less severe than is generally believed; and it enables non-brittle steels to be readily obtained by a suitable process of grading.

He prefers the small test piece of the Frémont type, which reveals local defects forming the germ of future cracks. He also attributes high importance to the velocity of impact and to the anvil bed, both of which should be considerable if the test be really desired to reveal the brittleness of the material.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

THE CONSTITUTION OF CAST-IRON AND THE EFFECTS OF SUPERHEATED STEAM.

By **William Campbell** and **John Glassford**, Columbia University, New York, N. Y.

It has been repeatedly observed that cast-iron fittings in superheated-steam pipe lines have been subject to a form of corrosion which causes them to swell, become brittle and fail. The worst specimens completely disintegrate, breaking down to a friable mass which may be crumbled in the fingers. It is also known that other cast-iron fittings have been used in superheated-steam pipe lines for years without showing signs of corrosion. It was the object of this investigation to determine

1. The nature of the corrosion.
2. Why some cast-irons corrode, while others do not.
3. How the corrosion can be minimized.

„The effect of Superheated Steam on Cast-Iron and Cast-Steel Fittings" was made the subject of a symposium at the Boston meeting of the American Society of Mechanical Engineers in December, 1909[1]). At this meeting Ira N. Hollis stated:

a) „Fittings have developed cracks and small changes of shape after a few months of actual service.

b) Fittings exposed separately to superheated steam at a temperature exceeding 500° F., have shown a permanent increase of some dimensions.

c) The tensile tests of pieces cut from fittings that had failed in service indicate in some cases the possibility of permanent loss of strength."

[1]) Jour. Amer. Soc. Mech. Eng., December 1909.

He does not consider the demonstration of loss of strength of fittings after long service with superheated steam as either complete or conclusive evidence that the superheated steam caused the loss. An $8 \times 6 \times 6$ - in T carrying steam at 175 lb. pressure and 500^0 to 580^0 F. began to fail in fourteen months. A chemical analysis gave

Carbon	3·47%
Manganese . . .	0·10%
Phosphorous . .	0·366%
Sulphur	0·062%
Silicon	1·41%

The tensile strengths of six pieces taken from different parts of the T were found to be

12,646
14,295
26,080
27,270
28,280 lb. per sq. in.

It was supposed to be air-furnace gun-iron. Samples cut from another fitting that had failed showed no loss of strength. Hollis concludes that the failures were due to the strains caused in the fittings by the expansion and contraction of the long pipe-lines in which they were placed, and that the superheated steam had nothing to do with it.

Arthur S. Mann at the same meeting stated that "extra heavy fittings and valves" have been used in a number of instances for superheated work. After a short time, six months or even less perhaps, cracks make their appearance, valves leak, seats become loose, castings grow in length and surface cracks become so large in size and in number that the casting is removed from the line. An ordinary commercial extra-heavy flanged T, 8 in. inside diameter, with a body $^7/_8$ in. and flanges $^5/_8$ in. thick, made of common iron having a tensile strength of 18,000 lb., will fail with superheated steam at 175 lb. pressure and 577^0 F. temperature (200^0 superheat). Within a year the inner surface will have a network of cracks, some of which will increase in depth till they extend through the body. The flanges will crack outward from the bolt holes and the fitting will become dangerous. He has found even steel fittings have failed with superheated steam. Out of 25 steel

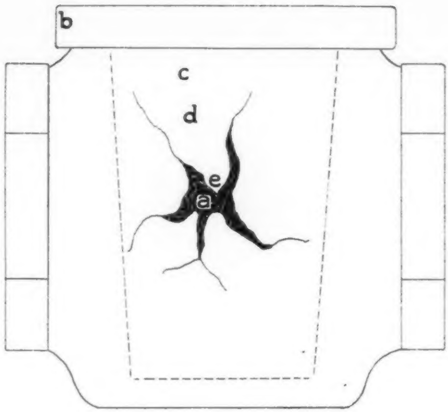


Fig. 1.
Cast Iron Plug Cock which Failed in Superheated Steam at 800° to 900° Fht. ($^1/_3$ size.)

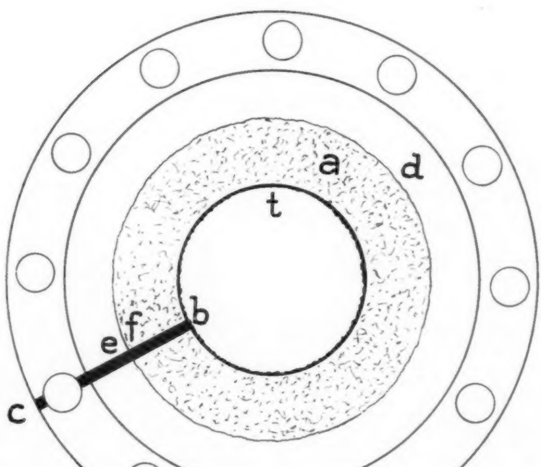


Fig. 2.
Cast Iron Flange Corroded in Superheated Steam. ($^1/_4$ size.)

a = Corroded surface exposed to steam.
d = Uncorroded surface protected by packing.
t = Thread, completely corroded.
bc = Section cut for microscopic examination.

gate-valves not more than four were fairly tight after one year's service. Some defects in the castings developed, allowing steam to pass straight through the walls.

The first of the following analyses is of an iron that has been successful in every respect for four years under 300° superheat, the other two are of castings which have failed.

	Sound %	Failed %	Failed %
Silicon	1·72	2·40	1·98
Sulphur	0·085	0·067	0·68
Phosphorus	0·89	0·94	0·65
Manganese	0·48	0·52	0·42
Total Carbon	2·45	3·19	3·31
Combined Carbon	0·17	0·25	0·24

Thinking that the growth that takes place in cast-iron on repeated heatings had something to do with its failure, Mann heated a sample of high-grade cast-iron which had proved itself capable of carrying superheated steam, and one of ordinary cast-iron, to a dull red heat for about four nights, cooling every day in the air. He found that the high-grade iron increased in length slightly more than did the ordinary iron, the experiment tending to show that the growth of cast-iron does not necessarily unfit it for the usual degree of superheat in powerhouse work.

Mann concludes that superheated steam does not of itsel initiate defects and it is not supposed that the sound metal undergoes a change, either chemically or structurally, but, if there is an initial defect, superheated steam is active in developing it. It is his opinion that silicon is the most injurious element present in the iron and that, though it is at present going too far to say that every high-silicon iron will fail and that every low-silicon iron will prove successful, there is much evidence pointing toward the correctness of such a surmise. "In any event iron of low silicon, low phosphorus and low carbon, in other words gun-iron, has proved successful." He therefore concludes that the remedy for the trouble is in the use of a high quality of cast-iron.

Edward F. Miller at the same meeting described a number of the tensile strengths of specimens of cast-iron, gun-iron, and

steel, which had been subjected to superheated and saturated steam. The results are tabulated below:

Specimen	Hours in Super-heated Steam	Hours in Saturated Steam	Loss of Strength	Graphite %	Silicon %
Cast-Iron . . .	260	460	2·4	3·02	1·88
" " . . .	260	460	9·5	2·84	2·26
" " . . .	520	920	1·8	—	—
Gun-Iron . . .	260	460	3·5	2·60	0·54
" " . . .	520	920	2·1	2·44	1·65
Semi-steel . . .	520	920	0·4	2·64	1·25
Steel	520	920	1·8	—	—
"	520	920	1·9	—	—
"	520	920	1·5	—	—
"	520	920	24·0	—	—

The results are irregular and not very conclusive, but it is evident that in general the metals tested have suffered a loss in strength due to their exposure to the steam.

Albert A. Cary[1]) believes, after examining a number of plants having trouble with superheated steam, that many if not most of their troubles are due to bad design in the piping arrangements. He thinks that there is little reason to believe that steam has any material chemical effect upon metal parts and that, at a temperature below 500° F., ordinary high-grade heavy fittings may be used. He cites tests at Watertown Arsenal where samples of gun-iron maintained their strength of 30,000 lb. up to a temperature of 900° F. At higher temperatures the strength gradually dropped, till at 1500° F. it had fallen to 10,000 lb. He thinks that without doubt a change in molecular structure occurred in this iron at a temperature of about 900° F., and probably with other grades of cast-iron such a change would occur at a still lower temperature. He adds that mild steel attains its maximum strength at 500° F., and with a further increase of temperature its strength rapidly declines. He has done no experimental work.

John Primrose[2]) thinks that superheated steam has been blamed for faults existing in the original castings. Though test-bars

[1]) "Iron Age", April 7, 1910.
[2]) "Power", June 8, 1909.

cut from fittings which had failed showed a loss of as much as 50% of the strength they were supposed to have, it was not proved that the loss was due to superheated steam, as fittings also failed in saturated steam. He states that no difficulty is experienced in Europe, where superheated steam has been in use much longer than in the United States. He mentions certain cast-iron fittings that have been in use in the superheater of a boiler in gases at 1000° to 1200° F., and containing steam at 175 lb. pressure and superheated 150° F. These were in use eight years and then showed no sign of defect.

A well-known metallurgist made microscopic examinations of sections of inlet fittings (saturated steam) and outlet fittings (superheated steam) from a superheater and found no difference in the structure of the iron and gave it as his opinion that none need be expected below 700° F.

On the other hand a fitting which failed carried steam with only 30° of superheat, while other fittings on the same line carrying much higher degrees of superheat were unaffected. He thinks that something more than superheat is necessary to destroy fittings, and that sudden variations in temperature or moisture content of the steam are probably most potent causes.

The various references to the "growth" of cast iron in heating make it necessary to consider this subject.

A. E. Outerbridge[1]) found that a cast-iron bar 1 in. square and $14^{13}/_{16}$ ins. long grew on repeated heating and cooling till it was $16^1/_2$ ins. long and $1^1/_8$ in. in width. He observed no increase in weight. The specific gravity changed from 7·13 to 6·01. Heating bars to 1450° F. increased the length $^1/_{16}$ inch per heat. At 1200° F. the rate of expansion is much less, and below a visible red so slight that he did not take the trouble to measure it. A 12 in. steel bar, on the other hand, shrank $^1/_8$ in. in 61 heatings. Wrought iron also contracted. Bars of an iron grating 10 ft. from the flame of a furnace grew from 22 to $24^1/_2$ ins. (11·4%) in length and $37^1/_2$% in thickness. He observed that high-silicon irons with low combined carbon expanded more than low-silicon irons with high combined carbon.

He thinks the change "is a molecular and not a chemical one, thus substantiating" his "original theory of the molecular

[1]) Journal Franklin Inst., February, 1904.

mobility of cast-iron. In gray cast iron the molecules or crystals are comparatively loosely tied together, the intermolecular spaces being filled with free carbon. In ordinary steel there is no free carbon and the molecules are more closely united ..... The molecules of cast-iron, being far more mobile than those of steel, tend to arrange themselves farther apart when the mass of molten metal cools slowly than when it cools rapidly, hence the more open grain,“ ..... Presumably Outerbridge explains the growing of cast-iron by a similar arrangement of the molecules farther apart when cooling from temperatures below the melting point.

Rugan and Carpenter[1]) mention that iron valves in superheated steam at 366° C. (691° F.) permanently increase in size but they think the phenomenon differs from the growth that takes place in air at higher temperatures.

On repeatedly heating samples of cast-iron in air to 600° C. no growth was observed. At 650° C. (1202° F.) a notable “growth“ was produced in two heatings. The rate of growth reaches a maximum when the heatings are to 860° C. For growth to take place both heating and cooling are required.

Three commercial gray cast-irons reached a maximum growth after 94 heats. Growths varied between 35·21 % and 37·5 %. An increase in weight accompanied growth in all cases.

White cast-irons containing no graphite and very little silicon (0·2 to 0·3 %) shrank 0·5 %.

High-carbon medium-silicon irons containing a little graphite grew 8·7 to 12·65 % in 60 heats.

Two white irons first contracted, then grew; and it was shown that both these irons became gray on heating, and that the change from shrinkage to growth coincided with the appearance of free carbon.

Gray irons with 3·4 to 3·98 % carbon and 1 to 6 % silicon grew from 15·4 to 63 % and increased in weight from 0·65 to 13·2 %. The growth in volume and weight was proportional to the silicon present, and during heating the silicon changed from a form soluble to one insoluble in hydrochloric acid.

Iron-silicon alloys without graphite did not grow.

One of the high silicon gray irons which grew 62 % in air contracted 0·04 % in vacuo with the evolution of 1·11 times its

[1]) Journal Iron and Steel Inst., 1909 No. 2, p. 29.

volume of gas. Another iron of the same kind, which was heated in vacuo till it ceased to evolve gas, grew 67·7 % when afterwards repeatedly heated in air. "The fully grown alloys have very largely lost their metallic lustre. They looked more like chalk than metal."

One alloy containing 3·4 % carbon and 6 % silicon which grew 3·5 % in air, grew 11·1 % when repeatedly heated in vacuo.

The gradual penetration of gases into the alloys during growth was studied microscopically and the structural changes recorded. Graphite is displaced from its original position — the spaces left are oxidized — and numerous small holes are formed. The structure is revolutionized.

The authors conclude from their experiments that growth is due to one or more of the following causes:

a) A partial oxidation of carbon, which diminishes with increase of silicon and becomes nil when silicon is 6 %.

b) A probable complete oxidation of silicon, originally present as iron silicide, to a mixture of iron oxide and silica.

c) A partial oxidation of iron uncombined with silicon.

d) A separation of free carbon by the decomposition of cementite.

e) The expansion of occluded hydrogen.

Rugan and Carpenter thus differ radically with Outerbridge on matters of both fact and theory.

In a second paper on the growth of cast-iron after repeated heatings,[1]) Carpenter found that phosphorus tends to diminish growth. Sulphur is never present in sufficient quantity to have more than a small influence on growth. Manganese retards the rate of growth in all cases and diminishes the absolute amount in the majority of cases. Dissolved gases have no influence on the growth of an iron containing more than 3 % of silicon. They may cause a growth of 1 to 2 % when silicon is between 1·75 to 3 %. When silicon does not exceed 1 % their influence is most and may be accountable for at least 10 % of growth.

Before taking up the examination of structures of iron that have been submitted to superheated steam it is necessary to say a few words about the constitution of cast-iron.

---

[1]) Journal Iron and Steel Inst. I 1911, p. 196.

The constitution of cast iron.

The iron-carbon diagram of Roberts-Austen[1]) as modified by Roozeboom[2]) shows that on freezing alloys of pure iron and carbon consist of two phases, graphite and a solid solution of carbon in iron (Austenite, 2 % carbon). At 1000° C there is a reaction between the austenite and the graphite to form carbide of iron or cementite (Fe_3C). At 690° C the austenite which has been precipitating cementite from 1000° down to 690° C, and now contains 0·9 % carbon in solution, splits up into a mechanical mixture of pure iron (ferrite) and carbide of iron (cementite). This is the eutectoid pearlite. Thus at normal temperatures the system consists of ferrite and cementite.

The diagram however is not in accord with the fact that by annealing a white cast-iron with 3.5 to 4 % carbon at temperatures from 750 to 950° C (malleabilizing process) the resulting product is ferrite and graphite.

To account for this there was developed the double-diagram[3]) in which we have two systems.

The stable system is ferrite and graphite, the metastable is ferrite and cementite[4])

Goerens and Gutowsky[5]) from an examination of specimens quenched at different stages during freezing found that austenite and cementite are the first phases to solidify and that graphite results from the decomposition of the cementite.

Carpenter and Keeling[6]) revised the data of Roberts-Austen and found two new lines on the diagram; one just below 800° C and the others at 600° C.

Lastly Upton in a paper on the Iron-Carbon Equilibrium[7]) gives his diagram showing that on freezing at 1145° C the phases are graphite and austenite. At 1095° C there is a reaction between austenite and graphite to form a new phase Fe_6C with 3.46 % carbon. At 800° C Fe_6C breaks down into Fe_3C with 6.68 %

---

1) Fifth Report, Alloys Research, Committee, Inst. Mech. Eng., London, 1899.
2) Zeits. Phys. Chemie. 34 (1900) 437.
3) Heyn, Zeits. Elektrochemie 9 (1900), 491.
4) Benedicks, Metallurgie 1908.
5) Metallurgie 1908.
6) Journal Iron and Steel Inst. I. 1904: Nat. Phys. Lab. I. 227.
7) Journal Phys. Chem. 12 (1908), 507.

carbon, and austenite. At 725° we have the change austenite with pearlite, while at 615° C the Fe_3C decomposes into ferrite and Fe_2C with 9·67% carbon. He concludes that Fe_6C, Fe_3C and Fe_2C are probably indistinguishable from each other in ordinary microscopic work. While the Upton diagram explains the changes in the iron-carbon diagram very satisfactorily it has not yet had the attention it deserves.

In comercial cast-irons which are not in a state of equilibrium we find the following constituents present: graphite, cementite (which may also be Fe_6C and Fe_2C of Upton), pearlite, and ferrite. These irons contain more or less silicon, manganese, and phosphorus. The silicon is completely soluble in ferrite[1]). The manganese may be partly dissolved in the ferrite and partly present as a double carbide of iron and manganese. The phosphorus is mainly present as phosphide of iron, Fe_3P, and is associated with the carbide of iron and forms a fusible eutectic when present in large amounts.

Experimental results.

For the investigation into the nature of the corrosion, two cast iron fittings were obtained, a plug cock and a flange, which had been in use on the outlet side of a separately-fired superheater for about two years. They carried steam at 50 to 75 lb. pressure and at a temperature of 800° to 900° F. The superheater was in use for six days a week and cooled down over Sunday. The two fittings are shown in Figs. 1 and 2. The cock was the most seriously affected. It had swelled, cracked and broken open as if by pressure from within. The metal at the point "a" was so friable that is could be crumbled in the fingers. It was black in color, with little metallic lustre and readily attracted by a magnet. Strangely, the metal on the opposite side of the cock was apparently unaffected. The mold mark was parallel to the sides, but which side was uppermost when the cock was cast could not be determined. The flange, Fig. 2, was corroded on the steam side as shown, but instead of expanding it showed an erosion of material of 16 in. on the inside and diminishing from this to nothing at the circle where the flange was protected by packing. The thread on

[1]) Gontermann. Zeits. angew. Chem. **59**, **373**. The solid solution of silicon in ferrite has been called silico-ferrite.

the inside of the flange was corroded through, and was almost as friable as the centre of the cock above described.

A chemical analysis of the pulverulent matter from the centre of corrosion on the cock yielded:

Iron	74·48
Graphite	1·17
Silicon	1·42

Four sections of the cock were made. These were polished and microphotographed.

Fig. 3 (x 50) shows the structure of the iron at the point of the cock b, in Fig. 1. This point is as far away as possible from the point of greatest corrosion. We can hardly assume, however, that the steam has had any influence. The plate shows the characteristic structure of cast-iron, thin plates of graphite in metallic groundmass On etching, the groundmass in seen to consist of some cementite with pearlite, while the graphite for the most part occurs in silico-ferrite. This is shown in Fig. 4 (x 50).

In Fig 5 and 6 (x 50) we have the outside and the inside of a section cut at a point much nearer the center of corrosion; c, in Fig. 1. In Fig. 5, the graphite shows up in nests for the most part, the groundmass being similar to that in Fig. 4, only about three times as coarse. In Fig. 6 the structure is even coarser than in Fig. 5; this is chiefly due to the fact that now we find a layer of oxide of iron formed as a sheet for each plate of graphite.

At the point d, the corrosion is very far gone and the graphite flakes with their oxide envelopes often form a continuous network. At e the corrosion has penetrated right through and the mass is porous. Fig. 7 (x 50) is from the outside, Fig. 8 from the inside, at d, both unetched. Fig. 9 and Fig. 10 are similar sections from e, both etched. It is seen that the silico-ferrite was the first to oxidize whilst the cementite goes last.

The flange was cut as in Fig. 2 and the structure examined from c to b. The variation in the coarseness of the graphite is much less than that shown by Figs 3 and 5 in the case of the cock.

The normal structure taken at c, is shown in Fig. 11 (x 50), (etched). Graphite in characteristic nests near the outside of the casting, passing into more plate-like forms as we get deeper in. The groundmass shows bright white cementite, associated with pearlite passing imperceptibly into silico-ferrite, in which the nests

of graphite occur. Moving over towards e, the structure changes and is shown by Fig. 12 (etched). A marked change has begun in the groundmass which reaches its maximum at f, and is shown in Figs. 13 and 14 (x 50, etched). Around the graphite flakes we now have thick envelopes of oxide. The groundmass has changed, especially the silico-ferrite, which now etches with brilliant colors. The pearlite has almost entirely disappeared as normal pearlite.

Reaching the center at b, the structure strangely enough changes back and is normal except at the inner surface where the threads have been corroded. Here we have a fairly thin layer with the structures shown in Figs. 13 and 14.

These changes due to corrosion can be progressively followed: First there is formed a thin envelope of oxide round the graphite, which enlarges the space occupied by the graphite and forms a crack which in turn is filled with oxide, and soon we get a complete network of graphite plus oxide. This change is noticed first in the silico-ferrite, as if that were the weakest member. While this change is going on there is a marked change in the metallic groundmass itself. The silico-ferrite changes over into a colored etching material (like austenite) and the normal pearlite disappears. The cementite is the last to oxidize. When the oxide plus graphite network becomes continuous the mass has become extremely brittle, in fact, it consists of metal cemented together by oxide and is naturally easily pulverized.

In order to follow the changes which occur and the effect of composition and structure when cast-iron is submitted to superheated steam, a number of specimens were heated in superheated steam at 425° C. (800° F.) and 95 lbs. pressure, for thirty and then ninety days, and their increase in size and weight and their microstructure recorded. Another set were heated in air to 425° C. and cooled down to room temperature, 72 times and examined.

Specimens treated.

1. Washed Metal.
2. White cast iron for malleabilizing. . . . . Si. 0·64
3. # 264 steel as cast. ·35 C ·66 Mn.
4. # 644 Malleable Cast Iron. . . . . Si. 0·88
5. # 800 1—1/4 in. dia. Sand Cast . . . . Si. 0·35
6. # 801 1 in. Sq. Sand Cast . . . . Si. 0·45
7. # 802 1—1/4 in. dia. Sand Cast . . . . Si. 0·70

8. # 803	1—1/4 in. dia. Sand Cast	Si. 0·95
9. # 804	1 in. sq. Sand Cast	Si. 1·25
10. # 805	1—1/4 in. dia. Sand Cast	Si. 1·35
11. # 806	1 in. sq. Sand Cast	Si. 1·95
12. # 807	1—1/4 in. dia. Sand Cast	Si. 2·00
13. # 808	1 in. sq. Sand Cast	Si. 2·19
14. # 809	1 in. sq. Sand Cast	Si. 2·5
15. # 795	1 in. sq. Sand Cast	Si. 1·48
16. # 796	1 in. sq Sand Cast	Si. 1·70
17. # 797	1 in. sq. Sand Cast	Si. 1·89
18. # 644	1 in. sq. pipe iron	Si. 1·75
19. # 657	# 3 Foundry Pig	Si. 2·0
20. # 660	"Silvery" Pig	Si. 5·5%
21. 799	Gun Iron.	
22. # 784	Cock Superheater	Si. 2·13
23. # 784	Flange Superheater	Si. 2·29

The first suite, heated for 30 days, consisted of Nos. 1, 2, 4, 18, 19, 20, 22, 23. No distinct measurable growth was observed except in the case of No. 20, which increased in length 3·7%. It also showed the maximum increase in weight of 1·4%.

The second suite, heated for 90 days, consisted of Nos. 3, 5 to 17 and 21, on which measurements were made. In addition specimens of the first suite which had been heated for 30 days were included for microscopic study only. The increase in length was irregular, with a maximum of about 2%; while the increase in weight was more irregular still and reached a maximum of 1·95% in the case of No. 14.

These results, while indicating that some change had taken place, were not enough to draw any conclusions. Under the microscope it was seen that the changes were mainly superficial. Therefore the main stress must be laid on the microscopical study of the specimens.

Summary of microstructure.

Washed Metal. The normal structure shows the usual coarse eutectic-like mixture of cementite and pearlite. Being treated for 30 and 90 days causes oxidation of the surface. Cracks caused in breaking off the specimens from the original piece are found to be filled with oxide also.

White cast-iron, for malleabilizing. Treated 30 and 90 days in superheated steam and by alternate heating and cooling in air gave similar results to the above. The only change is normal oxidation of surface.

264. Steel. Similar results. Surface oxidation only.

644. Malleable Cast Iron. Surface oxidation only.

800. Si, 0·35. The normal structure consists of fairly large, thin flakes of graphite, a little cementite, the whole in a groundmass of pearlite.

The 90-day treatment caused the usual surface oxidation, but in addition parts of the surface were swollen up and blistered by oxidation which has followed the coarsest graphite flakes. The alternate heating and cooling in air also gave some oxidation at the outside following the coarsest graphite.

801. Si, 0·45. }
802. Si, 0·70. } Similar results, even more marked.

803. Si, 0·95. Results as above. There is seen a trace of the new structure described in the next specimen.

804. Si, 1·25. The treatment in air mainly results in surface oxidation. Being heated for 90 days in superheated steam produces a new structure at the outside in addition to the normal oxidation. The oxidation follows the coarsest of the graphite flakes but around this we find a white border (presumably ferrite) forming an envelope to the whole. This new constituent must be produced from the pearlite. See Figs. 15 and 16.

805. Si, 1·35. } Show a similar structure at the outside, in-
806. Si, 1·95. } creasing in intensity with the silicon content.

807. Si, 2·00. Decomposition very marked. White borders to the oxidized-graphite flakes very pronounced. Fig. 15 (x 50, etched) shows the corner of the specimen.

808. Si, 2·19. } Similar change. Fig. 16 (x 50) shows a view
809. Si, 2·5. } of the side of the specimen (809) after etching.

795, 796, 797 and 644 are fine-grained irons. All show the regular surface oxidation after 90 days treatment but no white envelope, as in 804—809, where the oxidation has followed the coarsest of the graphite.

657. Pig. Si, 2·0, is similar.

660. Pig. Si, 5·5. Shows long graphite plates set in a groundmass of silico-ferrite with dots of cementite as seen in Fig. 17

(x 50). The 30-day treatment caused a marked change while 90 days caused the mass to become split up with planes of oxidation following the original graphite. The groundmass has altered and has precipitated a new constituent as a border to the oxidation planes. The whole has undergone a profound change, shown in Fig. 18 (x 50).

779. Gun-Iron. Normal surface oxidation with occasional penetration following some coarse graphite flake.

784 and 785. Cock and flange originally examined. Marked change after 30 days and more after 90 days treatment. Around sides and especially at the corners, oxidation follows graphite as above. The treatment in air resulted in the usual surface oxidation.

Conclusion.

a) White cast-iron, steel, malleable cast-iron, all show the same type of oxidation on treatment with superheated steam. The specimens have a regular skin of oxide which also fills any cracks that may be present.

b) The gray cast-irons up to 0·95% silicon, show a similar surface oxidation, but in addition there is a slight penetration of oxide following the coarsest of the graphite flakes.

c) The suite 795 to 657, Si 1·48 to 2%, show the same change.

d) The other suite, 804 to 809, Si 1·25 to 2·5%, show the above, the penetration increasing with the silicon content, and a new white constituent is precipitated round the oxidation planes. This is extreme in the case of the Pig 660 with 5·5% Si.

It is natural to conclude therefore in the case of the cast-irons the increase in silicon is attended by increase in corrosion. Were it not a fact that the pig 657 with 2% Si stood so well, a further conclusion that the finer the graphite plates the less the corrosion would be justifiable, and this would fit in with practical experience that good gun-iron stands up under superheated steam exceedingly well.

Summary of paper.

An examination of corroded cast-iron from a superheater showed that the metal had become oxidized following the planes of the graphite flakes.

A series of specimens were chosen, from white cast-iron with a trace of silicon, up to pig with $5{\cdot}5\%$, also malleable cast-iron and medium-carbon steel. These were heated in superheated steam at 425^{0} C. and 95 lb. pressure for 30 and 90 days; also in air to 425^{0} C. and cooled 72 times. On examination it was found that with the white cast-iron, malleable cast-iron, and steel, surface oxidation alone occurred. With cast-iron low in silicon there was a little penetration of oxidation, following the coarsest of the graphite flakes. The penetration increases with the silicon and with $5{\cdot}5\%$ Si the specimen was altered completely, when treated with superheated steam. Alternate heating and cooling in air mainly result in surface oxidation.

Fig. 3.

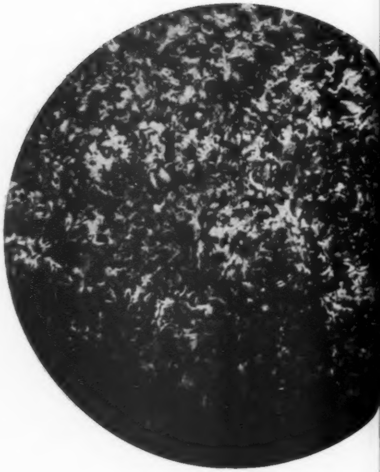


Fig. 4.

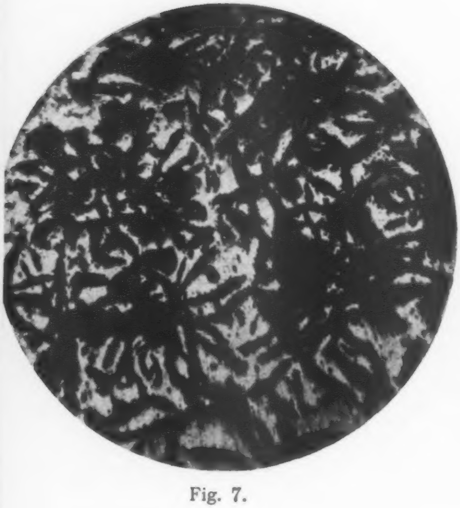


Fig. 7.

Fig. 8.

Fig. 5.

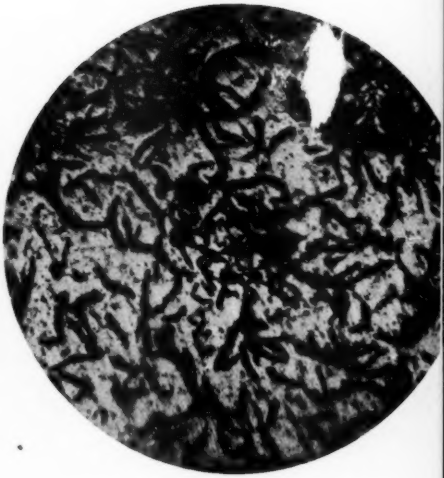


Fig. 6.

Fig. 9.

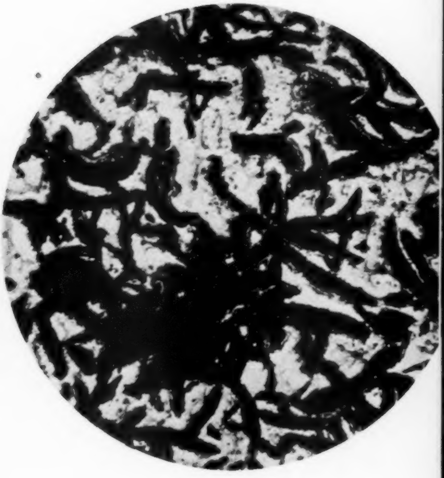


Fig. 10.

Fig. 11.

Fig. 12.

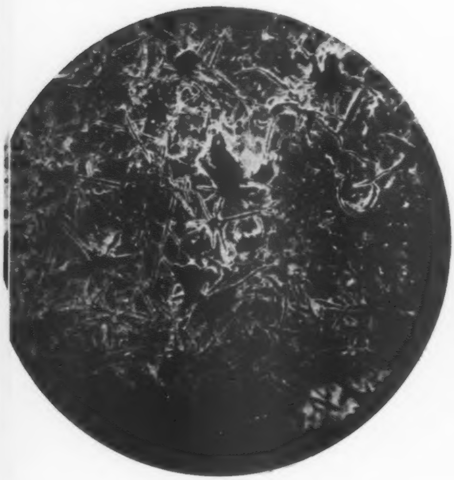


Fig. 15.

Fig. 16.

Fig. 13.

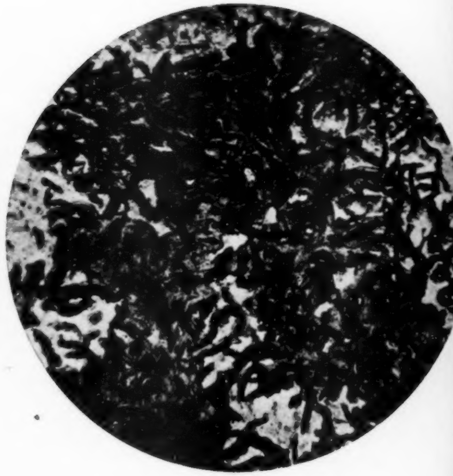


Fig. 14.

Fig. 17.

Fig. 18.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

A SUGGESTED SYSTEM OF TEST BARS FOR CHILLABLE IRONS.

By **Thos. D. West,** Cleveland, O.

This paper presents an original system for making comparative tests of the relative contraction, deflection and strength of chillable cast iron in both of its distinct forms: all-chilled or white, and all gray. The writer, for the past two years, has been experimenting with chillable irons in foundries making a specialty of chilled castings, and this has led him to vividly perceive the importance of a test system which can demonstrate the relation between the physical properties, of the white and gray states of the same metal, especially for such castings as chilled car wheels and rolls.

The origination of the system presented herein, was not only for the purpose for creating methods to study and possibly improve the ductility and strength of the white iron, without impairing the gray or mottled, to come from the same tap or ladle of metal, but also to offer a system that might lead to the adoption of some standard for testing chillable irons.

Until some practical form and size of test bars for chillable irons and methods for making them are adopted as a standard, a person desiring positive knowledge will obtain little satisfication in any study of test records or in making comparisons of his own findings with those of others.

Round bars cast on end.

The first important factor embodied in the system advanced herein is the use of round bars cast on end in preferance to square bars cast flat. The round bar cast on end, aside from offering the

greatest assurance of solidity at the point of fracture when broken, gives a form that is the least affected by variations in the pouring temperature of metal, dampness and grades of sands and irregularities of the molder's manipulations in the general work of making test bars. With reference to soundness it is to be said that few things are more agravating than, after expending much care and labor in testing bars, to find the fracture showing shrink holes, blow holes or sand holes.

A tested improvement for bearing points of round bars.

Objection has been made by some to round bars because they do not afford good bearing points to rest them on for testing purposes. The threepoint bearings seen at A, B and C, Fig. 9, remove these objections and in reality furnish a means of support excelling those non used with unfinished or rough square bars. The three-point support guards against torsional strains in the testing of either finished or rough test bars.

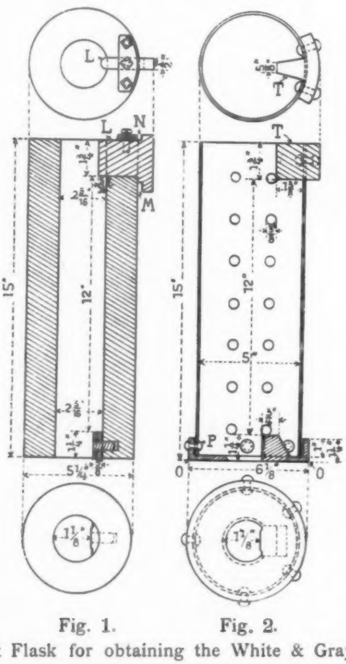


Fig. 1. Fig. 2.
Design of Chiller & Flask for obtaining the White & Gray of chillable iron.

Obtaining the contraction.

Much study was given to devising means which would guarantee correctness in obtaining the vertical contraction of the test bar. This quantity is measured by calipering the distance between the shoulders D and E (Fig. 8) for the gray bars, and between shoulders F and G (Fig. 9) for the white bars, and subtracting from the original distances the shoulders, J—K and H—I (Fig. 6). Should contraction records not be desired then the provisions for these measuring points could be dispensed with and the chiller be a plain body.

In providing measuring points for obtaining the contraction with the solid chiller Fig. 1, it is necessary, in order to remove the test bar, that one of the shoulder-forming projections be taken out or pulled back. With the design shown the arm L is drawn backward by driving the fork wedge Fig. 4 in the space M—N, Fig. 1. To arrange for making another bar the arm L is pushed back to the position shown.

In arranging to obtain the contraction for the all gray test bars a bottom plate O, Fig. 2, is riveted rigidly to a 5 in. wrought pipe P. A bottom plate of the thickness shown should be made of steel; if of cast iron it would be made thicker. The under face of this bottom plate should be machined so that it can set level and firm on the foundation plate Q, Fig. 6; similarly the bottom of the chiller should be machined. This will prevent the forming of any fins on the bottom of the test bars when pouring the mold, as such could, especially in the case of the white bar, cause checks to injure it.

In forming the projection seen on the gray bar at R, Fig. 8, and at J, Fig. 6, the device seen in Fig. 5 has its point S pressed into the sand, after drawing out the test bar pattern, by sliding it over the stationary rigidly riveted headpiece T, Figs. 2 and 6.

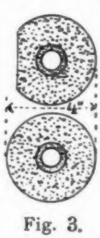


Fig. 3.


Fig. 4.

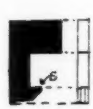


Fig. 5.

After the contraction shoulder points are firmly secured in their positions, to be as near 12 ins. apart as practical, exact measurements of their distance to the hundredth of an inch should be recorded. This is neccessary in order to obtain the correct contraction.

Making comparisons of round with square bars.

To determine the proper size necessary for the round bar, some experimenting was done. It was found that a $2^1/_4$ in. round bar should serve all general purposes for chillable irons containing from $0{\cdot}50\%$ to around $0{\cdot}90\%$ silicon, in combination with such total carbon, sulphur and manganese as generally used for chilled castings. Such silicons are within the range of practically all deeply chilled castings, especially car wheels and rolls. A bar of 2·267 ins. diameter is equal in area to a 2 in. square bar. This size of a round bar, roughly described as $2^1/_4$ in. diameter, can be well utilized in making comparisons with any 2 in. square bars that may be found advisable for conducting any special investigations.

The size of $2^5/_{16}$ in. given for the diameter of the bore of the solid chiller, Fig. 1, allows closely $^3/_{64}$ in. for the horizontal contraction of the white test bar· This contraction will permit an easy removal of the test bar from the solid chiller.

Designs of chillers to give white iron test bars.

For obtaining all-chilled or white test bars, a chiller or all-metal casting mold has to be employed. In obtaining the white bars for the author's experiments, the chillers used were made in halves and bolted or clamped together. Even with the best of machining and care in fastening these together, there is more or less risk of obtaining fins on the test bars. These fins can cause chill cracks or invisible ruptures, and thus often prevent a bar recording its full strength or deflection when being tested, by reason of the fins retarding the natural contraction of the metal. The author's experience causes him to recommend the solid chiller seen in Fig. 1 as being the best for general use. Such a chiller may be obtained by boring out a cored iron or steel casting, made after a manner to give a perfect, clean and solid bore; and again by boring out a solid shaft, which should serve the purpose even though $^1/_2$ in. less or more in outside diameter than given in Fig. 1.

To reduce the risk of obtaining an imperfect bore, the chiller might be made in two or three sectional lengths, having male-and-female seats and close-fitting joints. In making such sections no joint should be within two inches of the plane at which a bar is liable to break when being tested. This plan of a sectional chiller would permit its upper end being constructed the same as that seen for the lower end of Fig. 1 and would avoid the necessity of having the removable piece L, Fig. 1, and the forked wedge, Fig. 4.

Pattern and mold for the gray iron test bars.

The wooden pattern (Fig. 7) is made 18 ins. long, in order that 3 ins. of its upper end may serve for a handle to draw the pattern. The lower end of the pattern is made of the same form as the inner construction of the bottom plate O (Fig. 2).

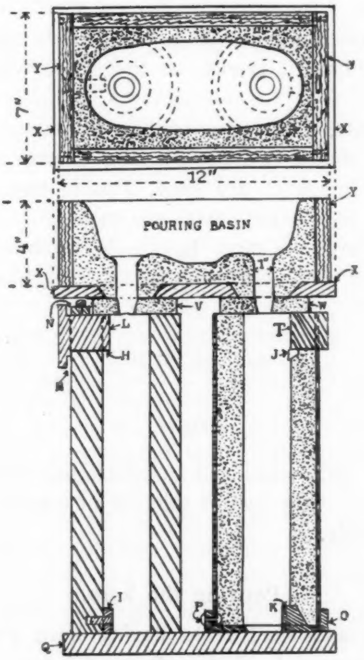


Fig. 6.
Chiller and sand mold ready for casting.

The top of the pattern as seen is $2^1/_4$ ins. in diameter and the bottom $2^3/_{16}$ ins., to give taper for drawing it. The mean diameter of this pattern, although about $^3/_{32}$ in. smaller than the

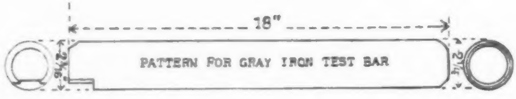


Fig. 7.

chiller mold, gives a gray bar closely the same size as the white one. This is due to enlargement of the mold by rapping the pattern, to ease it for drawing, and the hydrostatic pressure of the metal straining the mold, and also to the difference in the horizontal contraction of white and gray bars of the same metal.

The outside support for the mold being all iron permits the mold being either "dry sand" or "green sand", but if the latter, care must be exercised in always having closely the same "temper" of sand and ramming it evenly, so that there will be no "swells" on the test bars.

In cases where comparison of the white with the gray involves the detection of minute changes, or the silicon is below $0{\cdot}70^0/_0$, the mold is best made of dry sand. This is also advisable should novices have to be intrusted with the making of the mold.

The 5 in. wrought pipe, having $^3/_8$ in. holes, takes care of venting the mold. The chiller must be kept free from rust and

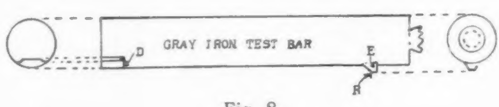


Fig. 8.

never moistened, with water and an occasional rubbing of its inner surface with a very light coat of thin oil or regular carwheel chiller varnish is advisable.

Pouring the bars.

The chiller and sand mold having been prepared they are placed on the base plate Q, Fig. 6, care being taken that there is no fine grit or dust to prevent a close jointing of the two bodies,

so as to avoid the formation of fins at the lower end of the bars. When the chiller and sand mold have been placed, cores as shown by Fig. 3 are set as at V and W in Fig. 6. An iron plate X is placed as shown, after which gate sticks are set in the holes of the cores V and W and the runner box Y placed in position. The pouring basin, formed of green sand, should be of good size so as to hold a fair body of metal. When starting to pour the mold the pouring basin should be quickly filled to prevent any dirt or scum from flowing with the metal into the molds

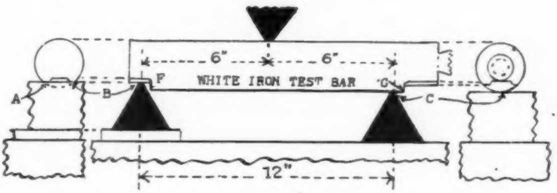


Fig. 9.

The pouring gates are but 1 in. in diameter in their main body. Their smallness helps to prevent dirt passing to the mold and also makes them easy of being broken off in cleaning the test bars. Their small size is very liable to permit the creation of small shrink holes in the tops of the bars. This being no serious defect it is better than having the gates sufficiently large to absolutely prevent such holes and cause the risk of injuring the bars when breaking off the gates. A small feeding-rod could be employed to feed the mold and make the tops of the bars solid, but to use this successfully requires considerable experience.

A $1^1/_4$ in. pouring gate could be used, especially for the all-chilled bar, to reduce the chance of shrink-holes forming. In this case, however, care must be used in skimming and in knocking off the gates.

While two molds are shown, as in Fig. 6, to be poured from the same basin for the purpose of insuring exactly like temperatures of metal in both molds, there are many cases where they could be poured independently of each other. In pouring the molds separately, with the same ladle, they can be so close together as to cause but a difference of five to ten seconds in pouring them. In pouring one mold after the other the cores (Fig. 3) could have

their tops made of a cup-form, to thereby give a small pouring basin to connect with the inlet gate. Again to simplify the work these top covering cores could in some cases be omitted and the metal poured directly from the lip of the ladle into the molds. In this instance care is necessary to prevent the dropping metal from striking the sides of the molds, or filling them any higher than within $^1/_4$ in. or $^1/_2$ in. of the top, so as to guard against an overflow making fins on top of the bars.

The system advocated herein is not merely formulated from ideas, but more from actual experiments to test it out in regular shop practice. The chillers used in these experiments, made after the writers designs, were kindly furnished him by Mr. H. E. Smith, Engineer of Tests for the Lake Shore & Michigan Southern R. R. Collinwood, Ohio. For chillable metal and the opportunity to test the system credit is due to the liberality of The National Car Wheel Co. Cleveland, Ohio.

A paper showing the utility of the above system of tests is, "Researches in and Tests of Chillable Irons" presented by the writer before the American Society of Mechanical Engineers at Cleveland, Ohio, May 1912.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR
TESTING MATERIALS".

RECENT RESEARCHES MADE AT THE NATIONAL PHYSICAL LABORATORY, TEDDINGTON, ENGLAND, ON THE RESISTANCE OF METALS TO ALTERNATING STRESSES.

By Dr. **T. E. Stanton,** Superintendent of the Engineering Department.

The investigations which have been in progress at the National Physical Laboratory from 1904 up to the present time on the resistance of metals to alternating stresses may be divided into two classes according as the resistance is that due to: —

1. Stresses alternating in a continuous cycle in which there is no instantaneous change in the value of the force on the specimen, although the period of one complete cycle may be as small as 0·02 seconds.

2. Stresses alternating between definite limits, usually tension and compression stresses of the same value, which are produced by a shock repeated at equal intervals of time.

Class I.

The first machine of this class which was constructed at the Laboratory was one in which alternations of direct tension and compression could be produced in the specimen at rates varying from 800 to 1300 per minute. The principle of this machine was that of Osborne Reynolds in which a rotating crank is used to produce periodic motion of a reciprocating mass by means of a connecting rod, the specimen under test forming a link between the reciprocating mass and the cross-head. In Reynolds' original machine only one crank was used, but in the machine at Teddington

4 cranks operating 4 specimens were employed and the reciprocating motion took place in a horizontal plane.

A diagram of the mechanism is shown in Fig. 1 which also explains the method of balancing the cranks. The results of the investigations with this machine when making 800 alternations per minute were in general agreement with those of Wöhler as far as the materials used could be compared, and at this speed there was no indication of the reduction in fatigue strength[1]) due to rapidity of alternation which had been found by Reynolds and Smith when using a similar mechanism at speeds of 1200 to 2000 a minute. In these experiments at Teddington the manner of failure of the specimen under direct stress was shown to be similar to that found by Ewing and Humfrey in the case of bending

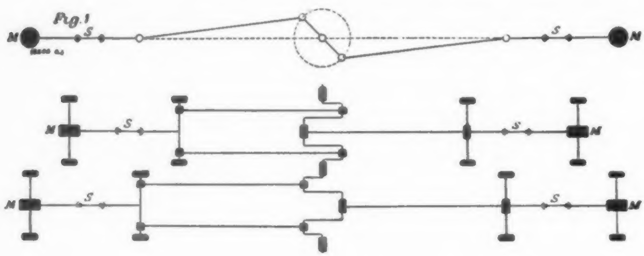


Fig. 1.

stresses, i. e. slip lines gradually appeared on the surface of the specimen, broadening out as the test proceeded, and finally developing into a crack. Further important results were the marked reduction in fatigue strength due to sudden changes in section, such as screw threads and sharp corners in the specimens.

The next investigation undertaken was that by Mr. L. Bairstow on the determination of the range of the elastic limits of iron and steel under cyclical variations of stress. In connection with this work it may be recalled that Professor Bauschinger in 1886 laid down the hypo hesis that the range of stress between the superior and inferior elastic limits in iron and steel is the same in magnitude as the maximum range of stress which can be repeated

[1]) The term "fatigue strength" is used in this paper to denote the maximum range of stress which a material will endure without fracture when the number of repetitions of the stress is unlimited.

without limit in a specimen of the same material without causing fracture. In a second paper in 1897 a series of tests made by Bauschinger with the object of experimentally verifying the hypothesis is discussed, but the experimental methods do not appear to have been sufficiently refined for the purpose of the determination and the results were indefinite. In taking up the investigation Mr. Bairstow made use of a testing machine in which cyclical variations of direct stress were automatically produced at the rate of 2 per minute in such a manner that the extensometer used, which was of the Martens mirror type, was fixed to the specimen throughout the whole of the fatigue test, and in this way the complete phenomena of the breakdown could be observed.

When the limits of stress were tension and compression of equal values it was found that, when the range of stress was above a definite value, the stress deformation curve formed a closed loop which was called the hysteresis loop, consisting of two parallel straight lines corresponding to the variation of stress from the limits of stress towards the mean stress and two curved portions corresponding to variations of stress from the mean value to the extreme values. The width of this loop which was the permanent "set" of the specimen per cycle increased as the range of stress increased, but for a definite range of stress tended to a limit which was not greatly exceeded by subsequent repetitions of loading even when this was the range at which fracture under fatigue eventually took place. Under these conditions of stress the mean length of the specimen remained constant.

When the limits of stress were unequal the hysteresis loop was formed as before but was not closed owing to the fact that the mean length of the specimen gradually changed owing to the continued repetition of the same cycle of stress, i. e. the change of mean length of the specimen per cycle was the amount by which the hysteresis loop was unclosed. The amount of the permanent extension during the earlier stages of the breakdown becomes considerable as the superior limit of stress approaches the static yield point and if its value after the first considerable stretch has occurred be plotted against the corresponding values of the superior limit it will be found that the curves will gradually come into coincidence with the ordinary static "force-elongation"

diagram at the yield point. The results of the research formed a very definite experimental confirmation of Bauschinger's hypothesis.

During the last two years another investigation has been in progress to determine the effect of rapidity of alternations on the fatigue strength of material. For this purpose a special machine of the Wöhler type has been constructed, and by the additional device of a dash pot to damp out oscillations, provision has been made for obtaining a range of speed from 200 to 2200 per minute. A long series of tests at speeds of 200 and 2200 cycles per minute have been carried out on three kinds of material, Swedish iron, Axle steel, and hard spindle steel. The results of these tests have shown conclusively that in no case is there any difference in fatigue strength due to a variation in the rapidity of alternations between these limits.

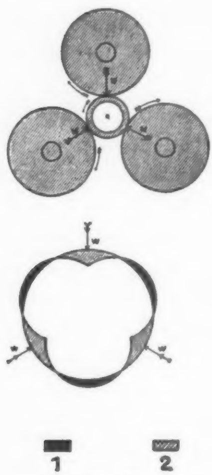


Fig. 2.
Distribution of stress at outer surface of ring,
1 = Tension,
2 = Compression.

Another method of high speed fatigue testing, in which the specimen is in the form of a hollow ring of rectangular section has also been developed as a check upon the foregoing results. The specimen R (Fig. 2) is placed between three hardened steel rollers symmetrically situated as shown. The upper roller is loaded with a weight W so that the ring is in equilibrium under three equal forces W at the lines of contact, and by rotating the upper roller motion is communicated to the lower ones by the rolling friction of the ring. In this way every radial section of the ring is subject to alternate bending stresses which go through a complete cycle three times in one revolution. In the machine constructed the diameter of the rollers was three times that of the specimen so that by rotating the roller at 250 revolutions per minute alternations of stress were produced in the specimen at a rate of 2250 per minute.

The superior and inferior limits of stress at the inner and outer surfaces of the ring can be calculated from the dimensions of the ring and the load. The distribution of stress at the outer surface is shown in Fig. 2.

The results of the experiments made with this machine were in agreement with those made on the Wöhler type machine referred to above both as regards the magnitude of the limiting ranges of stress and the independence of this range on the rate of alternation.

In view of recent confirmation of these results by Messrs.[1]) Eden, Rose and Cunningham and of the results obtained by Professor Hopkinson[2]) at alternations of 7000 per minute there appears to be little doubt that the previously observed reduction of strength with rate of alternation is due to some secondary stresses set up by the vibration of the particular machine used.

Class II.

In a research on the methods of impact testing at the National Physical Laboratory in 1907, from considerations of the fact that failure under shock in practice is generally due to a comparatively

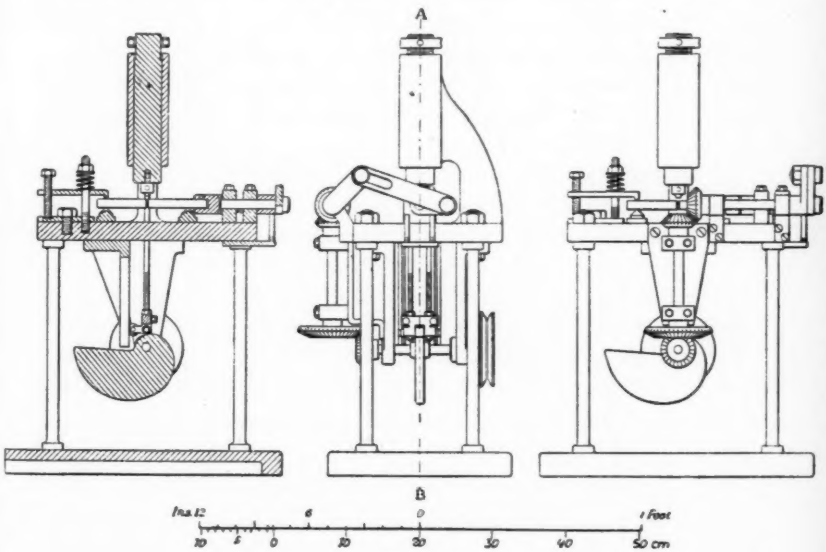


Fig. 3.

Repeated-Impact Testing Machine for Bending of Notched Specimens. (N. P. L.) Section on A B.

---

1) Proc. Inst. Mechanical Engineers 1911.

2) Proc. Royal Society Dec. 1911.

small blow many times repeated, a machine was designed and constructed for the subjection of a specimen to alternating shock stresses of equal and opposite sign.

The general arrangement of this machine is shown in Fig. 3. The specimen which is 12·7 mm diam. and has a V notch at its half span 10·1 mm diam., is supported on knife edges 114 mm apart and struck alternately at each end of a diameter of the notched section by a hammer weighing 2·13 kilos. The fall of the hammer can be adjusted between 0 and 89 mm.

In making a series of tests on any given material the first tests were made with a height of fall which caused fracture after a few reversals. Succeeding tests were then made with gradually reduced falls until the specimen was not broken after 1 million blows. A curve was then plotted and the limiting value of the blow for no fracture predicted from this.

In this way 4 curves were determined for 4 different materials of which the fatigue strengths under the Wöhler test were approximately known. On comparing the relative resistances to shock of these 4 materials it was found that when the number of blows for fracture was small, these relative resistances were in agreement with the respective energies absorbed in fracture with the single blow Impact test. (Charpy, Izod etc.) When, however, the number of blows was considerable, say 100.000, the ratios of these resistances was practically reversed, i. e. the material which was weakest under the single blow method now became the strongest. This is due to the fact that as the number of blows for fracture increases, the elastic resistance, which was inappreciable in resisting a heavy blow, becomes more and more important

Further it was noted that if the respective values of the proof resilience for these 4 materials were calculated i. e. the values of $^1/_2 \frac{f^2}{E}$ where f is the real elastic limit of the material derived from the Wöhler test and E is Youngs modulus of elasticity for the material, then the ratios of these resiliences were approximately the same as the ratios of the respective limiting values of the blow for no fracture after an indefinite number of blows. The conclusion therefore arrived at, was that, if the correct value of f could be obtained from the fatigue test of a material, then the value $\frac{f^2}{E}$ could be taken as a measure of its resistance to repeated shock stresses.

REPRINTED BY PERMISSION FROM THE "PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS".

NEW METHOD FOR MECHANICAL TESTS ON CAST IRON.

By **C. Frémont**, Paris.

(Translated by C. Salter.)

For a century, cast iron has been tested by bending test bars in the Monge apparatus. At present the most important specifications prescribe two tests: tensile strength and resistance to impact.

One government department recently made enquiries among the iron-founders on its list of contractors, to ascertain what test they considered the most suitable; but the answers received were so divergent that no practical conclusion could be formed. It is therefore interesting to compare the different methods of applying mechanical tests to cast iron. I have already published a first notice on this subject[1]), and to-day I will complete this investigation by presenting the results of supplementary tests.

This time I proposed to compare the results obtained, from one and the same cast iron, with statical bending, tensile, impact and shearing tests, and then to repeat these tests on a large number of pieces of cast iron of divergent origin.

In order to compare the results of the tensile and bending tests I operated on test 140 bars collected by an important department and derived from different foundries. In the heads of these test pieces I cut out small prisms measuring 8 by 10 by 30 mm., which were subjected to statical bending tests in a machine which recorded the amount of force applied. This machine was described in the former report.[1])

[1]) Bulletin de la Société d'Encouragement, Paris, May 1909. Mechanical tests for cast iron.

The results have been plotted on the graph (Fig. 1), the abscissae representing the force required to fracture the test bars in the bending tests, and the ordinates the corresponding tensile strength per square millimetre of sectional area.

In general it is found that two specimens of cast iron with an equal breaking strength under statical bending tests may vary considerably in tensile strength, the ratio being in some cases as high as 2 : 1.

Tensile strength.

Bending strength.

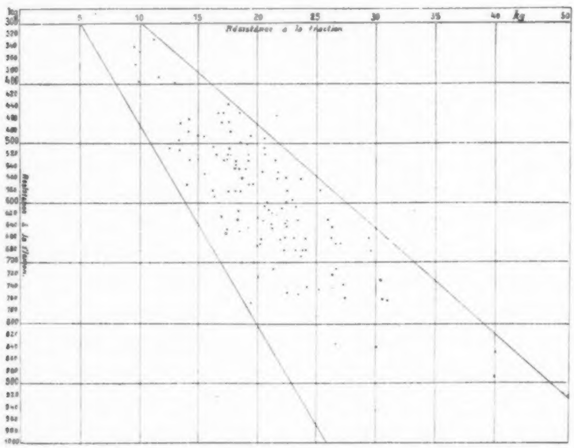


Fig. 1.

Graph furnishing a comparison between the tensile strength and bending strength of a cast iron. (The abscissae represent the force required to fracture the test pieces in the tensile tests, and the ordinates the corresponding shearing strength.)

Since, in the bending test, a prismatic test piece breaks by the tension exerted on the bent portion, one ought to obtain concordant results in both kinds of test (bending and tensile) when applied to the same cast iron, except for the differences due to heterogeneity of the metal. As this is not the case, some other intervening cause must operate.

Now, I have shown in my earlier report that the coefficient of elasticity of cast iron varies between wide limits, being up to three times as much in some cases as in others. Thus, for instance if we take two similar test pieces, one of inferior and the other

of very good cast iron, the bend produced under the same load in the bending test will vary according to the quality of the metal, and may be three or four times as great in cast iron of low quality as in the better quality metal under the same conditions. Owing to this high capacity of elastic deformation, the test pieces of poor cast iron will give in the tensile test, whereas, other conditions being equal, the test pieces of good cast iron break prematurely by flexion. The fact is well known to practical men, for it is often noticed in making tensile tests that the test pieces break in the holders, where the sectional area of the piece is much larger than in the body of same.

It will be evident therefore that if the differences observed in tensile tests (Fig. 1) are due, in the case of bad cast iron, to the heterogeneity of the metal, the cause of the differences cannot be the same in the case of good cast iron, but is due to the low elastic property which is inversely proportional to the strength of the metal.

I have vainly endeavoured to correct these deviations from the truth in the tensile strength of the test piece, by placing a pad of copper under each head. To compare the results of bending and shearing tests I have worked with 267 fragments of cast iron, derived in part from test pieces from impact and tensile tests, and in part from old castings.

The results have been plotted on the graph (Fig. 2), the abscissae representing the force required to fracture prismatic test pieces in the bending tests, as in the previous tests, whilst the ordinates give the corresponding shearing strength per square millimetre of sectional area.

This time we find that a sufficiently complete correlation exists between the two kinds of test: statical bending and shearing. I have made over two thousand tests and have been able to confirm that the differences are entirely due to the heterogeneity of the metal, and that they diminish in proportion as the quality is higher.

In order to compare the results of the impact and shearing tests, I operated on the fragments of 37 test pieces from impact tests carried out by a railway company. These pieces, of square section (40 by 40 mm.), which had been fractured by the impact of a 12 kilo. drop hammer, were sawn so as to furnish two

prismatic test pieces measuring 8 by 10 by 30 mm., one being taken from the edge and the other from the middle of the large test pieces, for the purpose of applying bending and shearing tests as in the preceding cases. The necessity for taking two test pieces was caused by the difference in the quality of the metal, the middle portion being weaker in consequence of segregation in the specially cast ingot. The results of these tests have been plotted on the graph (Fig. 3). In the abscissae, M represents the results obtained with the test pieces from the middle, and B those taken from the edge of the fragments broken by the impacts pro-

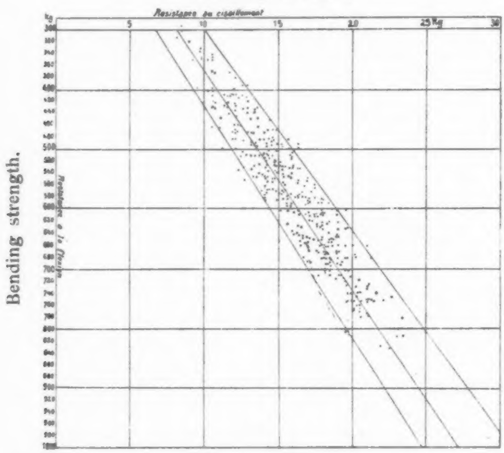


Fig. 2.

Graph showing that, in the case of cast iron, the shearing strength is proportionate to the bending strength. (The abscissae give the force required to fracture the test pieces in the bending test, and the ordinates the corresponding shearing strength.)

duced by the hammer falling from progressively increasing heights, viz: 40, 45, 50, 55, 60 and 65 cm. respectively. The ordinates give the results of the shearing tests per square millimetre of section aiarea.

One sees that there is no relation between the results of the impact bending tests and the shearing or statical bending tests (since we know that these two tests are in harmony). The cast iron specimens which fractured under a low height of fall — 45 cm. — gave shearing strengths varying between 10 and more than 21 kilos. per sq. mm.; whilst the specimens which required

the comparatively high fall of 60 cm. to produce fracture, gave shearing strengths of 12 to 20 kilos.

This great divergence between the results of the impact tests and of the statical bending or shearing tests is explained by the variation of the coefficient of elasticity in inverse ratio to the tensile strength of the cast iron. In fact, if we take the case of

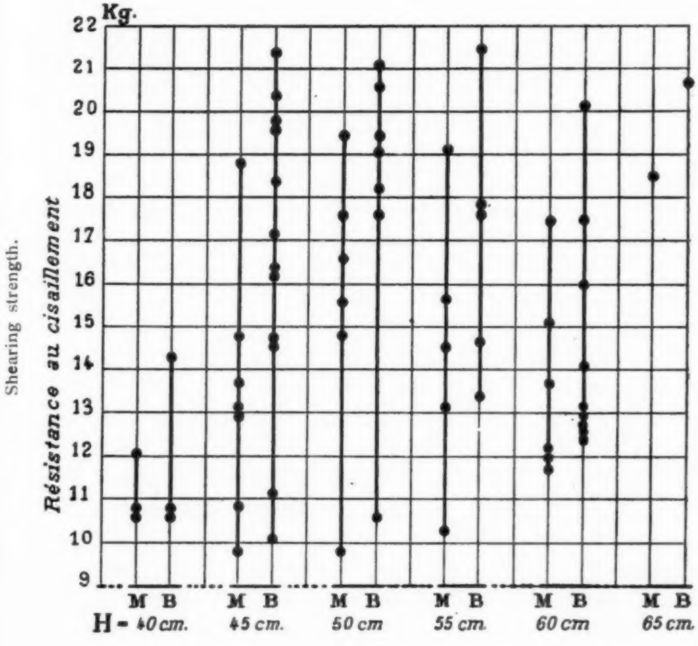


Fig. 3.

Graph furnishing a comparison between the results of impact and shearing tests. (The abscissae give the height of fall of the weight, and the ordinates the corresponding shearing strength.)

two similar test pieces, one of which, however, is of poor and the other of very good cast iron, the force necessary to fracture them by impact will differ but little, because though the force required to fracture the poor iron is smaller than that needed in the case of the good iron, the poor iron will bend more under flexion than the good iron, and there will be only a small differ-

ence in the product of the two factors, force and deflection, in the two cases. The presence of dust or oxide, forming a pad under the test pieces at the supports, or the use of a lighter anvil base, will constitute a sufficient cause to influence the results of the tests considerably.

It should also be noted that, although the impact test be necessary in the case of iron or steel because these metals, subjected to different conditions, may exhibit different methods of fracture, this test is not essential in the case of cast iron, this kind of metal exhibiting only one method of fracture between the grains, namely granular fracture, no matter whether the test be static or dynamic.

In short, it may be asserted that the impact bending test does not indicate the strength of cast iron: and that the tensile test can never be performed with sufficient accuracy, whatever the care bestowed and the precision of the apparatus, since the test piece can never be pulled in an absolutely axial direction. Statical bending and shearing are the only mechanical tests capable of revealing the quality of cast iron. The manner of taking the sample for testing is also of great importance; and tests applied to a test piece that is cast specially for that purpose will give only approximate information on the quality of the metal.

To obtain accurate information it is essential to take the test piece from the actual casting that is to be ultimately used in practice.

In order to attain this result one must be able to take small test pieces; and this I have done in the majority of instances by boring, in a special manner, holes which are intended ultimately for the purpose of assembling the castings, or else can be plugged up again if found necessary. These holes are 14 mm. in diameter, and are bored by a tool in the shape of a trepan, which leaves in the centre a cylindrical core 7·5 mm. in diameter. This core can be broken off with ease at the base, by a small special tool, and can then be shaped into a square prism of 5 mm. side. Shearing tests are applied to the prism at intervals of 3 mm. lengthwise, in order to ascertain the strength at the periphery and various depths.

These shearing tests will give accurate information on the quality on the cast iron, with rapidity and economy.

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS".

COMMERCIAL TENDENCIES IN MALLEABLE CASTINGS PRACTICE.

By Dr. **Richard Moldenke**, Watchung, N. J.

As is well known, the production of malleable castings is carried out in America almost entirely with a view of obtaining the "black-heart" variety, while in Europe the white steely fracture is the rule. The latter material may be readily machined and finished up with little loss of strêngth, while the "black-heart" suffers seriously if the skin of the casting is removed. The differences lie primarily in the heat treatment given the two varieties of malleable castings, in the percentages of phosphorus and sulphur used, and finally in the uses they are put to.

The question of strength is not always a serious one in malleable castings work, so long as a casting is intended to be finished up as part of a machine tool, or where the labor thus expended forms the principal item. Something a little better than cast-iron is wanted, and the malleable casting machines up easier than the steel one. Where, however, no labor whatever is intended to be expended upon the malleable casting, as is practically always the case with the "black-heart" American variety, there is the somewhat natural tendency toward making the least weight do the work.

Were this commercial consideration always accompanied with the proper understanding of the characteristics of the material involved, there would be no harm done. But where the consumer forces the manufacturer to take chances his better judgment would not sanction, then it becomes a serious matter. In the first case this continual demand for a better grade of material is a good

thing for the development of an industry, since stricter specifications are made and methods of production are improved; in short, a pound of iron is made to go further in the service of man than it could before. On the other side the following may be said: That in the entire range of the casting industry there is a present tendency toward running up the more striking characteristics of a material to a point of excellence at the expense of other but none the less valuable ones. For instance, instead of making use of the ordinary malleable casting, as readily made from good irons under standard conditions, a grade of cast-iron made with the plentiful addition of steel to the mixture, and advertised as "semi-steel", is substituted on account of its lower cost. Again, instead of using the steel casting direct, where a high tensile strength is desired, a very-low-total-carbon malleable casting is made to do because it is cheaper.

The result of this short-sighted policy is the production of a series of supposedly high-grade materials which in reality are very unreliable. The principal sufferer is the consumer who does not make any specifications, but gets the bulk of the metal that has to be made to satisfy the one who does. The latter, who may need only a limited quantity, asks for the almost impossible, and the product is probably entirely unsuited for general work.

Attention is directed to the above tendency in America at this time, because the export of "black-heart" malleable castings is beginning to be a factor in international trade. With a present American production of some **800.000** tons of these castings, and a capacity of over a million tons annually, there is bound to be some investigation on the part of consumers in other countries relative to the merits of the material in question. This in turn compels the producers of those countries to take notice and will naturally affect their practice.

So that the matter may be better understood, a few necessary details of production are given: In regular malleable melting practice, both in Europe and America, a limited amount of steel scrap is added to improve the material. This effects an initial reduction in the total carbon with a consequent increase in the tensile strength of the finished castings. With the very best of irons, short heats, first-class annealing conditions, and in fact the carrying out of the processes which are calculated to give the

best results, it is not possible to get a very high tensile strength without sacrificing some of the shock-resisting properties for which the malleable casting is justly famous. Thus, the ordinary "black-heart" product, as tested transversely by means of the 1 in. square test-bar placed on supports 12 ins. apart, should stand a load of 3000 lbs. applied at the center, and give a deflection of at least $^1/_2$ in., and in exceptionally good material the deflection may run even beyond $2^1/_2$ ins. The tensile strength of such test-bars will not run much over 42.000 lbs per sq. in. It is quite possible, by a heavy initial reduction in the total carbon through steel scrap additions, to obtain tensile strengths of above 58.000 lbs. per sq. in., and when extreme care has been exercised in the melting and annealing processes to keep oxidation of the metal down to a minimum the deflection will still be good. The chances are, however, so very much against this, even in the highest type establishments, that whoever insists upon this high-grade material and bases the calculation of his structures involving risk of life upon them makes a serious mistake. He had much better specify the steel casting in casting in the first place.

As a mere item to show the delicacy of the manufacturing process there may be mentioned the fact, well known to the producer but perhaps not at all to the consumer, that with composition and manufacturing processes identical up to this point, castings taken from saggers dumped on Monday morning — the one day when the annealing ovens are discharges cold — are much softer, bend and twist better, and are in every way more desirable as malleable castings, than those obtained the other days of the week. Yet the tensile strength of such castings is considerably below those dumped out hot.

The malleable casting differs from all others in that any attempt to correct the oxidation of the metal in a beat before pouring so increases the expense that it cannot compete with cast-steel. With the addition of much scrap steel to a charge, with the personal equation of the probable low type of melter, and with the probable variations in the annealing temperatures, an attempt to work for very high tensile strengths is not followed by reliable results. The chance of oxidizing the iron in addition to the silicon and manganese is such that a more or less open crystalline structure results, with consequent penetration of further

oxygen during the annealing process, weakening the casting. This may be readily seen from the effect of changing to coke irons from the charcoal varieties. Charcoal irons, with their high total carbon and comparative freedom from oxidation as blown in the furnace, when compared with the coke irons, gave the foundryman a chance to obtain good castings in spite of slight unavoidable variations in his practice. In American practice, at least, the change to coke irons has compelled the raising of the silicon specified in pig irons, in order to avoid this chance of initial oxidation as much as possible.

Until we have better melting methods (possibly when the electric furnace has been sufficiently developed along lines of economical production), and until we can obviate or cheaply correct any undue oxidation of the molten metal before it is cast, it would be wise to lay more particular stress upon the development of the malleable casting commercially along lines of greater softness rather than high strength. Where the latter is essential the steel casting is certain to replace it sooner or later. On the other hand, with the specifications so shaped that the resilience of the material is made prominent for ultimate development, the excellences of this peculiar product of the casting industry will be brought out and the material kept in its proper sphere of usefulness.

REPRINTED BY PERMISSION FROM THE "PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS".

ON UNIFORM NOMENCLATURE OF IRON AND STEEL.

Report of Committee 24, Presented by **H. M. Howe**, Chairman.

The Committee nominated for the solution of this problem is composed as follows:

Chairman of the Committee: Henry M. Howe, New York.

Vice-Chairman: L. Lévy, Paris; D. Tschernoff, St. Petersburg.

Secretary of the Committee: Alb. Sauveur, Boston.

Members: Van Drunen, Ixelles; O. Busse, Copenhagen; H. Brauns, Dortmund; Verein Deutscher Eisenhüttenleute, Düsseldorf (Repr: E. Schrödter); Jernkontoret, Stockholm (Repr.: I. A. Brinell, C. Benedicks, J. O. Roos af Hjelmsäter); F. W. Harbord, London; The Iron and Steel Institute (Repr.: J. E Stead); L. P. Sidney, London; A. Pourcel, Paris; H. Le Chatelier, Paris; F. Osmond, Paris (†); Comité des Forges de France (Repr.: Saladin, G. Charpy); P. Verole, Milan; Associazione fragli Industriali Metallurgici Milano (Repr.: Ing. C. Vanzetti); A. Baalsrud, Christiania; A. R. v. Dormus, Vienna; A. Sailler, Vienna; Bureau des forges, St. Petersburg; N. Belelubsky, St. Petersburg; Service du contrôle et de la réception des commandes du Ministère des voies de comm. (Repr.: O. Klemm), St. Petersburg; Edvi Illés Aladár, Budapest; Lázár Zoltán, Budapest; Misángyi Vilmos, Budapest; W. Campbell, New York; Jos. W Richards, South Bethlehem (Pa.); The American Society of Mechanical Engineers, New York; American Iron and Steel Institute (Repr.: Ch.

Kirchhoff, New York); American Institute of Mining Engineers (Repr.: Ch. Kirchhoff, New York); Henry D. Hibbard, Plainfield; H. P. A. Tiemann, Pittsburg.

I.
Introduction.

Introduction. With a few exceptions the definitions offered by your committee to the Vth Congress have been favorably accepted by the parties interested and we therefore recommend that they be accepted as standard. New definitions in place of those which seem to need amendment, and definitions of a few additional names, are proposed in § II of this report.

Two names "steel" and "malleable cast iron" need radical treatment in the opinion of part of this committee. Though colloquial and trade usage can easily tolerate two distinct and inconsistent meanings for a single name, scientific usage can tolerate them only reluctantly. Hence a some of us recommend taking steps to remove the inconsistencies connected with these two names, as set forth in § III and § IV of this report.

A few additions and amendments to the glossary of our last report have been proposed, but these are so few that we do not burden the present report with a new glossary, and instead we

---

II.
New definitions proposed to the VIth Congress.

Official Definition.

Cast iron: Definition. Iron containing so much carbon that it is not usefully malleable at any temperature. In America, besides the foregoing generic meaning, "cast iron" is used also in a specific sense which excludes "pig iron" (see below) and is restricted to cast iron in the form of castings other than pigs and to remelted cast iron suitable for such castings.

Remarks. The cast iron of commerce is reduced from the ore, usually in the iron blast furnace, in direct contact with solid carbon, and is then tapped from the furnace in a molten state. It

propose to include a revised glossary in our next report, which we hope may be our final one.

Several eminent gentlemen identified with the industry have proposed including in the definitions a statement of the apparatus in which the several products are habitually made, for instance specifying that cast iron is made in the iron blast furnace. But any substance which is identical in nature with cast iron should be cast iron in scientific language no matter how it is made, whether by melting in a crucible, by cementation, by a stroke of lightning, or by any other means now unguessed. Such restrictions do not belong in a definition, the purpose of which is to set up metes and bounds, to part the thing defined from the rest of the universe. But in order to meet their wishes, we supplement the definitions proper with remarks, clearly not defining but cautionary in their nature, which explain how certain of these products are habitually made. Such an explanation may well be useful as an added safeguard against fraud, because an industrial contract presupposes that its own language is to be read in the light of existing industrial conditions and usage. That may be "cast iron" scientifically speaking which is clearly not "cast iron" industrially speaking, as a blind or moribund horse, though still a horse scientifically speaking, is clearly not a horse for most industrial and administrative purposes.

II.

New definitions proposed to the VIth Congress.

British Definition.

Cast iron: Definition. Iron containing varying percentages of silicon, phosphorous, etc., and so much carbon that it is not usefully malleable at any temperature.

Remarks. The cast iron of commerce is reduced from the ore, usually in the blast furnace, in direct contact with solid carbon, and is then tapped from the furnace in a molten state. It always contains a considerable percentage of carbon, usually from about 3·0 to 4·5%, and in most cases an appreciable percentage of silicon.

always contains an important percentage of carbon, usually from $2{\cdot}5\%$ to $4{\cdot}5\%$, and in most cases an important percentage of silicon.

There are three chief varieties of cast iron.

Gray cast iron: Relatively soft, and characterized by the presence of sheetlets of graphite, often forming an irregular skeleton. This is the variety used chiefly for engineering work.

White cast iron: Extremely hard and brittle, characterized by having all or nearly all its carbon in the combined state, and by its consequent lack of graphite.

Mottled cast iron: Intermediate between gray and white cast iron.

Pig iron: Cast iron which has been cast into pigs direct from the blast furnace or its equivalent. This name is also applied loosely to molten cast iron which is about to be so cast into pigs, or is in a condition in which it could readily be cast into pigs.

Mixer metal: Molten cast iron which has been passed into or through a metal mixer.

Iron castings: Definition. Castings of cast iron.

Remarks. They are usually made from liquid iron direct from the blast furnace, or by remelting cast iron in a cupola or other furnace, or in crucibles.

Malleable cast iron: Definition. Iron which is first cast as cast iron and later made malleable without remelting.

Remarks. Commercial malleable cast iron is first cast as brittle white cast iron, and is then made more or less malleable either by converting most of its carbon from the state of cementite into that of temper graphite, or by removing most of it by oxidation, or by both means jointly. In both cases the malleablizing is done by close annealing, usually in contact with an oxidizing agent. Thus there are two classes of commercial malleable cast iron, of which one owes its malleability to a large removal of carbon, and the other to a large removal of carbon from the outer part of the casting, and to the precipitation of much of the remaining carbon in the free or graphitic state. It is not in accordance with good industrial usage to apply the name "steel" to any product

(in agreement with official report).

Pig iron: Definition. Strictly speaking, cast iron which has been cast direct from the blast or other furnace into moulds of varying sizes and shapes, known as pig moulds, and allowed to solidify in the form of pigs or slabs

Remarks. This name is also applied loosely to molten cast iron which is about to be so cast into pigs or is in a condition in which it could readily be cast into pigs.

Mixer metal (in agreement with official report).

Iron castings: Definition. Castings made by pouring molten cast iron into moulds of designed shape or form, other than in the form of pigs or slabs.

Malleable cast iron: Definition. Iron which is first cast into moulds and afterwards made more or less malleable without remelting, by close annealing usually in contact with an oxidizing agent.

Remarks. Commercial malleable cast iron is first cast as brittle white cast iron and is then made more or less malleable either by converting most of its carbon from the state of cementite into that of temper graphite, or by removing some of it by oxidation. In both cases the malleabilizing is done by close annealing usually in contact with an oxidizing agent. Thus there are two classes of commercial "malleable cast iron", of which one owes its malleability to a large removal of carbon and the other to a large removal of external carbon and to the precipitation of much of the remaining carbon in the free or graphitic state. "Malleable

of these malleablizing processes, or to any product made by remelting cast iron in a cupola or like furnace, and such application is generally held to be fraudulent.

Malleable cast iron differs from steel, 1. usually in containing more carbon, and 2. in being cast into a mass which is not initially malleable. Malleable cast iron is not strictly cast iron, but a distinct species, coordinate with wrought iron, steel, and cast iron.

Wrought iron: Definition: Malleable iron which is aggregated from pasty particles without subsequent fusion, and contains so little carbon that it does not harden usefully when cooled rapidly.

Remarks. Commercial wrought iron, though occasionally made directly from the ore, is usually made from cast iron by such removal of its carbon and silicon as to convert it, at the high temperature used, into pasty particles, and by squeezing these together in a bath of cinder or slag into a coherent mass which retains permanently an important quantity of that slag.

In Great Britain "malleable iron" is often used as synonymous with "wrought iron", but sometimes at the risk of leaving the lay reader in doubt whether it refers to wrought iron or to malleable cast iron. Hence we advise against this use of "malleable iron."

Steel: See "Carbon Steel" and "Alloy steel" below I. Fluid origin. Definition. Iron which is cast from the molten state into a mass which is usefully malleable initially at least in some one range of temperature. (See "Steel II," below).

cast iron" differs from steel (1) usually in containing more carbon, and (2) in being cast into a mass which is not initially malleable. Malleable cast iron is not cast iron, but a product of cast iron; it is cast iron which has been made malleable by special treatment and is as distinct from cast iron as wrought iron or steel which are also products of cast iron.

Wrought iron: Definition. Iron which is produced at a temperature below its own melting point either direct, from iron ore, or from cast iron as a malleable mass by the aggregation of pasty particles without subsequent fusion. It contains so little carbon that it does not usefully harden when rapidly cooled, is soft and readily malleable within wide limits of temperature and always contains intermingled slag.

(in agreement with official report).

Steel. Iron either pure or associated with other elements which has been cast from a molten state whether it hardens or not on rapid cooling from above its critical range and after solidification is so usefully malleable that it can be forged or rolled into merchant sections or shapes at least within some range of temperature; or, iron which has not been cast from a molten state and contains sufficient carbon to cause it to harden usefully when rapidly cooled from above its critical range and is so usefully malleable that it can be forged or rolled into merchant sections or shapes at least within some range of temperature.

The British Members of the Committee prefer the definition in the above form, but as the Committee of steel-makers suggested its division into two parts they submit it, thus divided, below, for consideration.

Steel. I. Fluid Origin. Definition. Iron, either pure or associated with other elements, which has been cast from a molten state whether it hardens or not on rapid cooling, from above its critical range and after solidification is so usefully malleable that it

Remarks. Such metal is steel whether it can be hardened or not, whether it contains much or little or even no carbon, and for that matter even if it is chemically pure iron. It is sometimes called "ingot metal". With the exception of "blister steel" and its derivatives all the steels which have any present industrial importance including the "alloy steels" (see below) fall under this definition.

These steels have been divided into:

a) **Ingot iron**: Steel with too little carbon to harden usefully on rapid cooling. This name has never been widely used, and for a long time fell into complete disuse. It has lately been revived as a trade name. It should be avoided in scientific and technical writings because, with the iron-carbon alloys divided into the four great species, 1. wrought iron, 2. steel, 3. cast iron, and 4. malleable cast iron, it is confusing to call a variety of "steel" "ingot iron".

b) **Ingot steel:** Steel with enough carbon (say **0·30%** or more) to harden usefully on rapid cooling.

Steel made by melting in a crucible is called "crucible steel"; that made in an electric furnace is called "electric steel".

Steel: **II.** Plastic origin: Definition. Iron which is aggregated from pasty particles without subsequent fusion; is malleable at least in some one range of temperature; and contains enough carbon (say 0·30% or more) to harden usefully on rapid cooling from above its critical range.

Remarks. Blister steel and its derivatives and a few other high-carbon steels which are unimportant today, are the only present steels covered by this definition.

Blister Steel: Steel of plastic origin made by cementing wrought iron with carbonaceaous matter Also, commercially, such steel when heated and worked into merchant sizes. Most writers have used "blister steel" in the former and broader sense. In Sheffield it is used solely in the latter and narrower sense.

Remarks. The blister steel of commerce is made by cementing very pure wrought iron with charcoal.

Blister Bar, Cement Bar, Converted Bar; bars of blister steel.

can be forged or rolled into merchant sections or shapes at least within some range of temperature.

Remarks. Such metal is steel whether it can be hardened or not, whether it contains much or little or even no carbon, and for that matter if it is chemically pure iron. It is sometimes called "ingot metal". With the exception of cemented bar, blister steel, and shear steel, and a few similar steels, all steels which have any present industrial importance fall under this definition.

a) and b) in agreement with official report.

Steel II. Plastic Origin: Definition. Iron which has not been cast from a molten state and contains sufficient carbon to cause it to harden usefully when rapidly cooled from above its critical range, and is so usefully malleable that it can be forged or rolled into merchant sections or shapes at least within some range of temperature.

Remarks. Cemented bar, blister steel, shear steel, and a few other high-carbon steels are the only commercial steels covered by this definition.

Blister Bar. Cement Bar. Converted Bar. Definition. High class Swedish or other wrought iron bar of equal purity which has been subjected to a process of cementation in contact with charcoal, which process, while introducing carbon into the iron also develops blisters on the surface of the cemented bar.

Blister Steel: Definition A term sometimes used to describe cemented, converted or blister bar which has been heated and worked into merchant sizes.

Plated bar: Definition. Bars of blister steel which have been rolled or hammered while hot.

Remarks. This treatment, which is usually applied to such bars broken to convenient lengths, flattens down their blisters and toughens the metal somewhat.

Single-shear steel: Definition. Shear steel made by welding a pile of plated bars into a faggot. Also the bars and other merchant shapes made by rolling or hammering such a faggot.

Double-shear steel: Definition. Shear steel made by piling, hammering, and thus welding bars of single-shear steel into a bloom. Also the bars and other merchant shapes made by rolling or hammering such a bloom.

Carbon steel: Definition. Steel which owes its distinctive properties chiefly to the carbon as distinguished from the other elements which it contains.

Remarks: Though among the alloy steels some are but moderately malleable, among the carbon steels industrial usage confirms the name "steel" to products malleable enough to be rolled or forged into merchant shapes.

Alloy steel: Definition. Steel which owes its distinctive properties chiefly to some element or elements other than carbon, or jointly to such other element and carbon.

Remarks. Some of the alloy steels necessarily contain an important percentage of carbon, even as much as **1·25%**. There is no agreement as to where the line between the alloy steels and the carbon steels shall be drawn.

Ferro alloys: Definition. Iron so rich in some element or elements other than carbon that it is used primarily as a vehicle for introducing that element in the manufacture of iron or steel.

Remarks. The ferro alloys are not usually usefully malleable, and they usually contain more of the alloying element than is desirable in an alloy steel. With variations in industrial conditions the line between alloy steels and ferro alloys must needs shift. Indeed, a substance might simultaneously be an alloy steel in the machine shop and a ferro alloy in the steel mill.

Plated bar: Definition. Blister bar or cemented bar which has been broken into suitable lengths, heated and hammered out to confer some toughness and to flatten down the blisters.

Shear steel: Definition. Steel made by piling and welding plated bars under a thin layer of suitable flux. The welded bars are drawn down under the hamm er into a faggot which is forged into merchant sizes, and is known as "single" shear steel.

Double-shear steel: Definition. If the single shear steel faggot be nicked, bent back upon itself, the two parts heated, welded and again hammered down, the resulting bloom is known as "double" shear steel. The merchant sizes forged from these bloomes are also known ar Shear Steel.

Alloy steel, Ferro alloys, (in agreement with official report).

Semi Steel, a vague trade name for various products near the border line between steel and cast iron. Among these are low carbon cast iron made in the air furnace, or in the cupola furnace by the addition of steel scrap to the charge. Also a trade name for malleable cast iron.

III. Steel and malleable cast iron.

Your committee is divided concerning two anomalies in present nomenclature, 1. that what is called "malleable cast iron" lacks the essential and defining property of other cast iron, lack of useful malleableness at all temperatures, and 2. that what is called "blister steel" lacks the essential and defining property of other steel, its being cast from a molten state into a mass initially malleable. A part of your committee proposes but the minority opposes taking the initial steps to rid first scientific, then technical, and finally industrial nomenclature of these anomalies, by removing malleable cast iron from the class "cast iron" and blister steel from the class "steel", and giving these species new distinctive specific names. The initial step proposed is formulation in Section IV of this report of propositions touching this subject, with the purpose of bringing out the arguments for and against this plan. If after thorough discussion either or both these amendments of the classification should still seem wise, your committee would propose to offer to the VII[th] or **1915** Congress the necessary resolutions and definitions for putting these amendments into effect. Though this matter has been under discussion in a general way for nearly forty years, yet in deference to the wishes of the British members we do not ask any formal expression of opinion from the VI[th] Congress.

All agree that these anomalies exist; that the only one important quality which the various varieties of cast iron apart from malleable cast iron have in common, and therefore their one defining characteristic, capable of serving to distinguish them from other kinds of iron, is that they are not usefully malleable at any temperature, whereas alleable cast iron is very malleable; and that the only one important quality which the various varieties of steel other than blister steel have in common, and therefore their one defining element, is their having been cast into a mass initi-

British definition.

Semi Steel (in agreement with the official report).

---

ally malleable whereas blister steel is not so cast. All agree that if malleable cast iron and blister steel were removed from their present classes of cast iron and steel, and given distinctive names, our nomenclature would be simplified and made more consistent, and that this greater simplicity and consistency would, taken in and by themselves, be good. But as to the expediency of taking the first steps in this direction we differ.

Were these steps once taken, the nomenclature might be given greater precision by defining "useful malleableness" quantitatively; but this further refinement might well follow the initial step of moving distinctly in the direction of qualitative consistency.

A glance at the roughly parallel case of the science of ichthyology and the fish industry may clarify the matter. They have the same ultimate purpose, to benefit man; but their means differ radically. Ichthyology must needs proceed scientifically, i. e. systematically and with precision. Its usefulness demands these conditions. Precise and consistent terminology forms a needed part of this system and precision. Consistency compels ichthyology to exclude mammals from the class "fish", and hence it excludes whales. But the fish industry stands in a radically different position. It has no need of consistency of nomenclature, based on specific characters. Hence it speaks of whales as "fish". It refuses to respect the nomenclature of ichthyology, though properly accepting everything of industrial value which that science lays bare.

But of the two, it is the ichthyologist rather than the fish industrial that gains the ear of the rest of educated mankind through his lectures and writings. As with the secular progress of education an increasing proportion of the educated take their language from the ichthyologist, more and more adopt the scientific nomenclature which excludes whales from the class fish, first because it is the nomenclature of those who have their ear, second

because they like its consistency. They come to regard as ignorant and ill educated those who think of the whale as a fish. With the further progress of the world, an increasing proportion of the captains of the industry receive an education high enough to familiarize them with the scientific nomenclature, and adopt it because of the human wish to be ranked with the educated. From like human motives the fashion thus set works down to ever lower levels. So in time by the working of natural processes the consistent nomenclature slowly displaces the inconsistent, and the revolution is complete This is one of the mills of the gods which, though it grinds slowly, and sometimes seems to stop grinding, yet in the end surely grinds exceedingly small.

Applying these considerations to our present case, there is the metallurgical industry, and there is the science of metallurgy. Till lately the industry has dominated the science completely. The science has been little more than the direct handmaid of the industry, serving mankind only indirectly and through the industry. But the time will come and may have come already, when the science must do its own independent work in its own way, as the sciences of botany, ichthyology, geology, and mineralogy do theirs. In one case as in the others the intellectual work of the science confers its ultimate material benefit on mankind through the administrative work of the industry which it directs, botany through the farming and the lumber trade, ichthyology through the fish trade, geology and mineralogy through the mining and metallurgical industries; but in one case as in the others the time comes when the science refuses to sacrifice its efficiency and its power of expressing itself to mankind apart from the industry which it serves, by submitting to inconsistencies of nomenclature which are irksome and hampering to it, however easily tolerated by the industry. In each case the degree to which the science does its intellectual and experimental work apart from the industry, and addresses itself primarily to itself and to the public and only secondarily to the industry, increases progressively and irresistibly. The science comes to demand more and more insistently that it shall be freed from inconsistencies of nomenclature. It points out that though these inconsistencies are more hampering to its work which is primarily intellectual than to the work of the industry which is primarily administrative, yet the simplifications on which

it insists for its own sake will in the end be a convenience to the industry itself.

In 1876 metallurgical science made a struggle against existing inconsistencies of nomenclature, but it was too weak to succeed. The industry will always be inconvenienced temporarily by any change, however useful it may be in the end, and, naturally mindful of that present inconvenience rather than of the convenience to posterity of inheriting a consistent and convenient nomenclature, monetary system, or system of weights and measures, is likely always to oppose every such improvement, however useful. Hence the survival of pounds, shillings, and pence, and the postponement of the universal adoption of the metric system.

Without proposing the impossible task of making trade nomenclature consistent, we may now ask "Has metallurgical science grown enough stronger in these thirty-six years to enforce its demand for consistency of nomenclature for its own use, in addressing itself and the rest of mankind apart from the industry?" We believe that all other branches of science of which there are industrial applications have such a nomenclature. Has the time come when we are strong enough to erect and maintain one, or must we wait yet awhile? That we shall be strong enough one day cannot be questioned. Are we today? A part of your committee believe that we are, and that we should now take the initial step already indicated.

As every body of men in enforcing their rights must respect the rights of others, so must the men of science, as the weaker party, scrupulously respect the rights of the industry. The industry naturally refuses to adopt the changes which we propose for the sake of consistency and clearness. This refusal is within its rights. It has a right to retain the existing inconsistencies. This right we must respect. Beyond this, we must do nothing likely to facilitate fraud.

In order to carry out this program we give in this present report the present names and the corresponding definitions, for present use; but we formulate proposition reciting the facts, and recognizing that the interests of science and of the public require that these inconsistencies be removed by removing the steels of plastic origin from the class "steel" and malleable cast iron from the class "cast iron." These proposition are not offered for adoption.

They aim to focus the matter and bring out the arguments for and against our plan.

If reason appears to be on our side, we expect to recommend to the VIIth Congress that it advise that the resultant consistent nomenclature be used in scientific and technical writings, but to record industrial usage.

If this course is followed, a strictly consistent nomenclature and definitions will be available for scientific purposes, and yet the trade usage will not be affected except gradually as it adopts the usage of science.

We believe that such consistent nomenclature, if authorized by a body of such weight as the VIIth Congress, will be welcomed by scientific writers and teachers, because of its consistency. Taught by them through their writings and addresses to their hearers, readers, and the public, it will be adopted gradually by technical writers because of its consistency. Because it is the fittest it will survive, and in the fullness of time will drive out the inconsistent nomenclature.

We cannot shut our eyes to the fact that the co-existence of the two different meanings of steel, based on radically different definitive properties, the "hardening power" for "steels" of plastic origin, and "fluid origin" for other steels, not only makes our nomenclature inconsistent, but causes it to shift from one inconsistency to another according to the needs of the hour. This situation offers a strong temptation to play upon these two meanings in such a way as to set a given product in the then best selling class. There are many varieties which, by this play upon meanings, may be shifted from "steel" to "iron" and back, according to which of these names is at the moment the more attractive to the public. For instance, prior to Bessemer the hardening power was the essential defining property of "steel"; but those interested in the Bessemer process disregarded existing nomenclature, set up the fluid origin as the defining property, and called all Bessemer products "steel" whether they would harden or not, "steel" being then associated in the public mind with superiority. Today the tables are turned; "iron" is associated in the public mind with superiority, and commands a higher price than "steel" of like composition. Just as in Bessemer's days certain

makers sought how to include their product in the class "steel", so today certain others seek, perhaps unconsciously, how to exclude theirs from that class.

Those who make a special low carbon open hearth steel exclude it from the class "steel" by adopting the hardening power as the definitive property; whereas makers of puddled steel exclude their product from the class "steel" by adopting fluid origin as the definitive property.

Both may be acting in perfect good faith. In some cases they evidently are. It is not they but the co-existence of contradictory meanings that is to blame.

As the trade refuses to be bound by its own inconsistencies, but shifts thus from one to another, playing upon the confusion which it has itself created, it is well that science should step in, select the dominant usage, and say "I will adopt this usage, and my character is warrant for its fixity; you may shift from one usage to another as you will, but with Homer's helmsman I will keep my rudder true, and because my usage is consistent and fixed you will eventually recognize it as the standard .

Turning now to the question of fraud, we have never heard that the fact that the definition of "fish", adopted by the educated world apart from the fish trade, excludes whales, has ever worked anybody a hardship, unless it is a hardship to whalers to be excluded from the caste of "fishermen"; nor can we conceive probable contingencies under which that exclusion could facilitate fraud. In the same way we fail to conceive probable contingencies under which the proposed exclusion of blister steel from the class "steel" in a strictly scientific nomenclature can facilitate fraud. If those who fear such fraud will really face the matter, and ask themselves how it can come about that fraud should result from giving a scientific definition of steel, "iron cast from the molten state into an initially malleable mass", coupled with the explanation of the industrial uses of the word "steel", we believe that they will find that this fear is not only utterly vague but groundless, a nebulous creation of their own imagination. If in any way it should suggest to the buyer of blister steel not to pay an irresponsible and unknown seller before having some reason to believe thai hts purchase corresponds to his needs, that does not

seem to us a hardship which should forbid our making our nomenclature consistent.

To couple a statement of existing industrial usage with the strict scientific definition would prevent the use of the scientific definition for customs frauds and other legal frauds, because where scientific and industrial usage differ, the customs-laws and judicial interpretations in general are necessarily based on the accepted industrial meanings. Contracts, expressed or implied, are necessarily interpreted as being based on the meaning presumably attached by the contracting parties to their own words, and these parties, in entering into their contract, clearly must have industrial rather than scientific considerations in mind.

But beyond this, the complete prevention of fraud is not a proper function of a definition. The definition of "horse" properly includes blind, lame, and moribund horses; that of "fish" properly includes decayed fish. A lexicographer who framed his definitions in general so that they excluded from the various classes all individuals save those most useful industrially, would be as mad as the purchaser of a horse who paid for it without some reason, from inspection, from the known character of the seller, or from other sources, to believe that it was neither blind, lame nor moribund, unless blindness, lameness, and death happened to be harmless for his special purpose. Equally insane, in our opinion, would be the purchaser who paid for a given lot of steel without some reason to believe that it was of the kind which he needed, be that reason a contract expressed or implied as to its composition or properties, be it the known character of the seller, be it the brand of the steel, or be it what you please. Your committee does not understand that one of its duties is to protect the reckless from the consequences of their recklessness.

The fear that our proposition would cause confusion seems to us to rest equally on misapprehension. To fix our ideas, let us suppose for the moment that the name selected for "blister steel" were "blister metal" and that the name selected for "malleable cast iron" were "malleablized cast iron", and let us further assume that the names actually selected shall be fit, shall suggest clearly the colloquial name to which they correspond, and shall not be likely to be confused with other existing names, whether precise or colloquial. The effect of our proposition would not be to remove the words

"blister steel" and "malleable cast iron" from industrial use; to attempt that would be like trying to stop the east wind. It would simply degrade them from their present position of being part of scientific nomenclature to being current colloquialisms. The technically educated man would know that the strict scientific name "blister metal" corresponds to the colloquial name "blister steel", and the scientific name "malleablized cast iron" to the colloquial name "malleable cast iron". He might indeed continue to use the colloquial name except where precision was called for. The mere fact that a name is colloquial and not part of scientific nomenclature is no bar to its use. The speech and the informal letters of most of us abound in colloquialisms, if not in slang. Is the fish trade hampered or confused by the fact that ichthyologists call whales "mammals"? And would the steel industry be confused by our using the name "blister metal" or "malleablized cast iron" in technical writings? For a very large number of our common words strict and colloquial meanings exist side by side, and for many of our common objects accurate and colloquial names exist side by side, without causing confusion.

Experience proves that when, for purposes of a consistent scientific nomenclature, a substance is removed from the class in which it has stood till then and set in another class, no harm is done to the industry which makes or deals in that substance. Whales were removed from the class "fish" to the class "mammal"; oil of vitriol from the class "oil" to the class "acid"; carbonic and phosphoric acids from the class "acid" to the class "anhydride"; oil of wintergreen from the class "ether" to the class "ester"; black lead from the class "lead" and given a new name "graphite". In the previously existing and wider meaning of their several class names, sulphuric acid was distinctly an "oil", carbonic and phosphoric acids distinctly "acids", oil of wintergreen distinctly an "ether", and black lead distinctly "lead". But for consistency of classification, these classes were narrowed so that each became a consistent unit, by excluding the several alien substances, which were thereby transferred to new classes These transfers caused absolutely no harm to the several industries, indeed in some cases had no effect whatsoever on the industry and were even unknown to the majority of the industrials. To this day these several substances are called in the industry by their old names to a greater or less extent.

The case of graphite is particularly instructive. Formerly confused with galena, as is shown by their both being called "plumbago" then, its true nature was not discovered till 1779 and its name "graphite" was not proposed till 1789. The name "lead" then and now colloquially and industrially included not only metallic lead, but also black, white, and red lead. Indeed for the graphite crayons of our pencils there is no familiar name except "lead", and these pencils themselves are universally called "lead pencils". Before 1789 metallic lead and graphite probably were not thought identical, but both were "lead", i. e. "lead" was a generic name. If there was any difference in the closeness with which this name was identified with these two substances, then for all we know it may have been identified more closely with graphite than with metallic lead. Exactly so, nobody thinks that blister steel is identical with steel of fluid origin, and the name „steel" has been used longer for steels of plastic than for those of fluid origin. But in the one case as in the other the need of precision and consistency in scientific nomenclature leads us to narrow the scientific meaning, that of "lead" to metallic lead, that of "steel" to fluid origin steels, for the simple reason that no other mode of narrowing it to a consistent unit offers. No reason suggests itself why the removal of blister steel and malleable cast iron from the classes in which they do not belong should do harm or cause confusion, seeing that the parallel removal of graphite from the class "lead" was harmless.

Let those who fear confusion from the coexistence of standard scientific and colloquial words and meanings ask themselves frankly whether those who habitually use colloquial words and meanings are in fact confused when careful writers write of "tin plate" instead of "tin".

Let them ask what trade was hampered or confused when whales were transferred from the class "fish" to the class "mammal", or is hampered by the fact that trade still calls them "fish" and science "mammals"; or what trade is confused or hampered by removing black lead from the class "lead" and re-naming it "graphite", or by the present co-existence of the names "black lead" and "graphite", or by the co-existence of the colloquial meaning of "lead" which includes "graphite" and the scientific meaning which excludes it? The fear is simply the fear of the

unknown, the unrealized, the unimagined; the fear of every change as change, because of failure to imagine correctly the conditions which the change will actually create.

Some unfamiliar with the conditions have thought that there is an inconsistency between the attitude expressed concerning "cast iron" in the 4th paragraph of this report and the proposition to remove blister steel from the class "steel". But the slightest examination shows that no such discrepancy exists, as we will now explain.

That wrought iron and low-carbon steel must for the present continue to be distinguished by means of their origin, the plastic origin of wrought iron and the fluid origin of such steel, nobody questions. The importance of distinguishing between these two classes is self evident. We all recognize the influence of the presence, quality, and distribution of the slag of wrought iron, its facilitating welding, its increasing the plasticity under certain important conditions, its lowering the transverse ductility, etc. etc. But when we try to frame words which shall express this difference by means of positive inherent properties as distinguished from origin we fail He who shall frame such words will thereby open the way to a great improvement on our classification and definitions. We cannot distinguish wrought iron from such steel by its greater slag-content; for some such steel contains more slag than some such wrought iron, and so on with each of the points of difference. Collectively their importance is neither questionable nor questioned, but nobody has yet found a way of framing words which shall distinguish these two classes from each other in terms of these unquestionably important inherent properties. Therefore, awaiting the coming of the framer of such words, we must needs be content to base the distinction between wrought iron and such steel on origin, a poor way philosophically speaking, but yet a perfectly effective and good working substitute for a better, and therefore to be retained till that better appears.

This being the case the proposal to remove blister steel from the class "steel" is not a proposal to set up origin as a new basis of classification but to extend its use to the strictly analogous purpose of parting high carbon steel of fluid origin from blister steel which is of plastic origin, and thus making our classi-

fication consistent by using the same basis for low and for high carbon products.

Some say "Why should not identical properties in the case of blister steel and crucible steel of like composition cause them to be classed together?" This is a mere befogging of the issue. We deny most emphatically such identity of properties. It may be true that for certain specific purposes such blister and such crucible steel may be equally well fitted, but that is neither here nor there. For certain specific purposes low carbon steel and wrought iron may be equally well fitted; horses and oxen may be interchangeable for plowing, nevertheless they deserve distinctive names.

If it were practicable to erase the present "origin" basis of distinction between low carbon steel and wrought iron and to use the hardening power as the basic quality of steel, we should concede the utility of discusing the relative appropriateness of the two bases, according great weight to the priority of the hardening power as a basis. But because, as all admit, the origin basis must needs be retained for parting the low carbon products, and because origin is therefore the only single element available, we maintain that the use of "origin" should be extended from the low to the high carbon products, more specially because this extension of this "origin" basis to the high carbon products would cause a minimum of shifting Puddled steel, which was formerly grouped with blister steel, has spontaneously ceased to be called puddled steel, at least in America. There remain only blister steel and its immediate derivatives, an altogether insignificant and moribund class, not made in America nor we believe to any important extent in any country except England. Moreover, this class of products interests only a very small class of men, who would not pay the slightest heed to the narrowing of the class "steel" in a strictly scientific classification so as to exclude blister steel, but would go right on calling it blister steel, and would be no more affected than the black lead industry is by the scientific exclusion of black lead from the class "lead".

Returning now to the case of cast iron, its basic property is its unalterable brittleness, and not its origin. That of low carbon steel is necessarily and regrettably its origin. The fact that consistency can be had only by extending this basis of "origin" to the high carbon products, fluid origin steel and blister steel,

furnishes no excuse for introducing origin in to the definition of cast iron. Further, that to which we object is not the use of origin as a basis of cast iron, but restricting cast iron to the product of a special kind of furnace, a restriction which has nothing in common with the use of origin as the basic element in steel. We are forced to part wrought iron from low carbon steel, not by specifying the kind of furnace in which it must be made, but by fluid vs. plastic origin. Were the proposition to restrict cast iron also to material of fluid origin, it might be debatable. But the proposition to restrict cast iron to the product of a single kind of furnace appears to us indefensible.

Is it not true that, with the sole exception of metallurgy, every branch of science which is related to an industry has its own nomenclature, which coexists with the industrial nomenclature without harm to either? Are the farmers, florists, and lumbermen harassed because the botanist uses his more precise Latin names? Do they not purposely adopt those more precise names when they wish to be exact? Are the dealers in horses, fish, sheep, cattle, bird plumes, and the like plagued because the zoologist uses his more precise Latin names? Do they not often turn to those names when they need special exactness? Some think that, when we metallurgists who are specially interested in the science as distinguished from the art of metallurgy propose to make our own nomenclature consistent we are doing some unheard of thing. But is it not the truth that in our supineness we have deferred to this astonishingly late date the enforcement of that right which every other branch of science long ago enforced, and enforced without any harm to the allied industry, the right to a consistent nomenclature? We believe not that consistency and precision of language tend to confuse, but that to defer making language systematic and consistent is to prolong confusion.

The foregoing part of Section 3 represents the views of part of the Committee; the view of the British members are as follows:

The British Members of Committee 24 regretfully find themselves compelled to dissent from some of the most important views expressed in Section 3 of this Report prepared and therefore are obliged to state their own views. After consultation with a special Committee of British manufacturers appointed to confer

with them, they have drafted a few alternative definitions which they herewith beg to submit for consideration.

The chief points of difference in the definitions are in respect of 1) Steel; 2) Wrought iron; and of 3) Malleable cast iron. With the exception of these, they have, with a few modifications, adopted almost in their entirety the proposed official definitions and the remarks thereon.

The British Members understood that the Committee was appointed not to introduce new names in the places of old ones, but to define clearly existing terms as they are understood by technical men. They take the strongest exception to the recommendation to remove Steel of Plastic Origin from the class of Steels, and to give these and Malleable Cast Iron new names. The steels in question possess the well-known property of hardening and tempering, which until a few years ago, was regarded as the essential and distinctive property of Steel. If these recommendations should be accepted, large quantities of cutlery steel, shear steel, and other material, which have for generations been known as steel will have to be excluded, and they consider that any attempt to re-name such well-known materials would be impracticable, lead to confusion and greatly discredit the work of your Committee and that of the Association They therefore consider it is not only undesirable but worse than useless to attempt to introduce new names for well-known products, such as Cemented Steel Bar, Shear Steel, Malleable Cast Iron, etc With regard to the term "Malleable Cast Iron", it may be admitted that this is not in itself an ideal one, but it has become incorporated in technical literature and by common usage is now so well understood by technical men that the British members cannot see how any useful purpose would be served by altering the name; provided it is carefully defined, less confusion would, in their opinion, arise by retaining the existing term than by any attempt to introduce a new one. In England, and, so far as they are aware, on the Continent, "Malleable Cast Iron" has never been classed with cast iron, but has stood by itself, and there has never been any confusion between it and "Cast Iron" amongst technical men.

In view of the great difficulties of carrying on a discussion by correspondence with Members of the Committee in all parts of the world, and in many cases speaking different languages, the British Members are of the opinion that the detailed discussion

and full consideration of the various views expressed, have not been possible to the extent necessary to enable the Members of your Committee to exercise that considered judgment, which is so essential to enable them to arrive at a decision on questions of such far-reaching importance. They therefore most strongly support the Official recommendations that the questions raised in Section 3 be fully discussed, but that the Congress should refrain from committing itself to any official expression of opinion thereon and defer action until the views and criticisms of the whole of the Members of the Committee have been further elicited.

IV. Propositions to be discused but not voted on at the VI[th] Congress.

I. Whereas every scientific classification should be based on characteristics fit for this purpose so that all the members of each class shall have in common the defining characteristics the possession of which constitutes that class:

II. And whereas, the present classification of the products of iron and steel, however well fitted for the present industrial needs, offends this law in regard to the classes "steel" and "cast iron", first in that blister steel lacks the essential defining characterics of all other steels, "having been cast from the molten state into an initially malleable mass" which all other steels have, and in virtue of which these other steels are grouped into the class "steel"; and second in that "malleable cast iron" lacks the essential defining characteristics of all other cast irons, viz: that their "malleableness, if any, is below the useful limit at all temperatures", in virtue of which characteristics all other cast irons are grouped into the class „cast iron";

III. And whereas these inconsistencies hamper scientific writers and speakers seriously, and tend to confuse their readers among all educated classes, save and except only those familiar with the industry itself, and thereby to obstruct the diffusion of knowledge concerning iron and steel outside the industry;

IV. And whereas the interests of the body of scientific investigators, teachers, writers, their readers, and the public outside the industry, have become so important in the premises as to demand recognition;

V. And whereas though the systematizing of its classification by any branch of science, especially if it is related to an industry, usually results in degrading certain names, or certain inconsistent and contradictory meanings of such names, from their initial position within good usage into colloquialism; yet experience proves most abundantly that this degradation in fact works no hardship and causes no confusion in the industry, which in its current usage disregards such degradation and is not deterred in the slightest degree from continuing to apply a name by the fact that such application has thus become colloquial and not scientific; so that the benefit which science and the outside public derive from the consistency is not offset by any damage to the industry, which remains a law unto itself in regard to trade names;

VI. And whereas blister steel and the allied steels of plastic origin are of only slight importance except in Great Britain, and some of them have elsewhere spontaneously ceased to be called "steel" even industrially;

Now therefore it is believed.

1st, that, for the purposes of a strictly scientific nomenclature as distinguished from industrial nomenclature, malleable cast iron ought to be removed from the class "cast iron";

2nd, that, though in Great Britain the name "steel" has become so firmly attached to blister steel and the allied substances of plastic origin, that it is inexpedient to attempt now to remove them from the class "steel" in industrial, commercial, and colloquial usage, at least in that country, yet such removal is desirable for the purposes of a strictly scientific usage, which should adopt the dominant defining characteristics of "steel", the combination of malleableness with fluid origin, and reject the co-existing but inconsistent defining property, "the hardening power".

REPRINTED BY PERMISSION FROM THE
"PROCEEDINGS OF THE INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS".

TYPICAL AMERICAN USES OF CAST-IRON, AND TEST METHODS APPLICABLE TO THEM.

By **John Jermain Porter**, Staunton, Va.

American foundry practice has made great progress in passing from the empirical stage to that of scientific control. A most important feature, the use of chemical analysis as a basis for mixing irons, is now practically universally adopted, but much still remains to be done both in the more efficient use of chemistry and in the adoption of other scientific methods of control.

It is now becoming quite widely recognized that chemical composition is not the only factor determining the properties of cast-iron, but, although the importance of structure is known, the methods of metallography have received very little attention from foundries and users of castings. It is true that investigators have used the microscope on cast-iron with valuable results, but this method of control has not yet been generally taken up in practice as in the case of steel. The two reasons which apparently account for this neglect are: first, the fact that foundries being operated in smaller units, have as a rule less technical skill available at each individual plant; and, second, that the more complex structure of cast-iron makes the interpretation of its microstructure much more difficult. It is probable that much of the metallurgical progress of the near future will be along this line.

The theory that oxygen and nitrogen may be present in cast-iron and are accountable for some otherwise inexplainable phenomena is gaining ground among practical foundrymen, and means of eliminating these elements are being widely adopted.

Greater care is being given the cupola process, and the use of ferromanganese, silicon, vanadium and titanium as deoxidizers is rapidly increasing. Ferro-alloys are also rather extensively used to correct the composition of the iron in the ladle.

Since cast-iron is used for a wide variety of purposes, it is obvious that the properties by which its value is measured and the tests to which it is subjected should be different for each class of castings. Hence it is necessary to consider each class separately. It is true that current practice does not as a rule adequately recognize this fact, and almost the only test which is commonly applied is that for transverse or tensile strength, although this property in many or perhaps the majority of cases is not of chief importance. There are but few foundries in this country devoting attention to getting special properties in this material, and to most foundrymen, as well as users, cast-iron is simply cast-iron, and a casting is satisfactory when true to pattern and free from visible defects.

The succeeding portion of this paper will discuss some characteristic American uses of cast-iron, the properties needed, recent progress in meeting these needs, and the tests necessary to define the desired properties.

I. Machinery Castings.

A large percentage of machine parts are made of cast-iron, which material is especially adapted for this use on account of the ease with which it is cast and machined into the desired shape. The more important properties desired in machinery castings are softness, strength, and a fine grain-structure, in addition, of course, to freedom from visible defects such as blowholes, cracks, shrinkage cavities, etc.

It is an easy matter to make soft castings, but to get the combination of easy machining properties, strength, and close grain, as demanded by some users, has proved a difficult proposition to many foundries. Especially is this true as to closeness of grain and the ability to take a high polish, which is so desirable on many finished parts. The solution has been reached in various ways. The use of charcoal iron is one method, satisfactory except from the standpoint of cost. Certain brands of coke irons are found to give greater strength and closer grain for a given softness

than others, and the knowledge of such mixtures is a valuable asset to the practical founder. Another method is found in the use of steel scrap in the cupola mixture, making the so-called semi-steel, which gives a closer grain-structure and considerably more strength without material change in composition. The treatment of the metal with certain ferro-alloys has also been found advantageous in this connection.

The buying of machinery castings would be greatly simplified if definite limits of hardness, strength, and grain size, could be specified. Satisfactory methods for testing hardness are found in the drill test and the Shore scleroscope, most of the various other proposed methods being too cumbersome for commercial use. The drill test, simulating as it does actual machining operations, gives the more reliable results, while the scleroscope possesses the advantage that it can be used directly on the casting without in any way injuring it.

For testing the strength of cast-iron there are available the ordinary transverse, tensile and compressive tests, the first of which is, in the opinion of the writer, preferable. In the testing of strength (and hardness also) it must be remembered that the properties of cast-iron depend in part upon the thickness of the section, and hence that, in cases where it is not possible to test the casting itself, the testpiece should at least approximate the section of the casting. Probably three standard sizes of test-bars could be selected, to represent the three classes of light, medium and heavy castings. The broken ends of these bars could be then used for the drill test to determine hardness.

For grain size there is no practical test available: a serious lack, as in many cases this property is of the greatest importance. Possibly something might be done with a planimeter used on a microphotograph of standard magnification; a rough test, of value in some cases, can be made by comparing the fracture of a broken test-bar with a scale made of previously broken test-bars of varying grain size.

The freedom from blowholes and other casting defects is best determined by ocular inspection. Unfortunately there is no method of inspecting the interior of the casting without destroying it, and while the tendency of the iron to shrinkage, blowholes, etc.

can easily be tested, such tests would be of doubtful utility since these troubles are frequently, if not usually, due to faulty molding and pouring.

II. Hydraulic Work.

Cast-iron is still very generally used for this class of work, on account of the ease with which it is formed into shape, although there has been some attempt to substitute steel for very high pressures. The properties desired in the metal are practically the same as in the preceding case, except that they stand in a different order of importance, close grain and freedom from shrink-holes and spongy places being the first consideration. Much the same means are used to obtain the combination of density, strength and the ability to machine easily, but as the importance of density is greater in this case, the use of special means, such as charcoal irons, steel scrap and ferro-alloys, is more frequent.

The most direct and satisfactory test for hydraulic work is to subject the casting itself to some specified hydraulic pressure. In many cases, however, the casting cannot be so tested until a good deal of expensive machine work has been done on it, and in this event it seems advisable to specify the strength and hardness tests previously described. The hardness test should be used in any case, as the bursting strength does not, of course, give any idea as to machining properties. A test for grain-structure would be especially valuable in connection with this class of work.

III. Electrical machinery.

For parts where high electrical permeability is of prime importance, cast-iron has been largely displaced by steel, but in the majority of cases it still holds its own on account of the greater ease of forming. The permeability of cast-iron, although always low as compared with that of the purer forms of iron, can be considerably improved by keeping the manganese very low and the silicon quite high. In practice however, not much attention is usually given to this property, since the greater number of castings are used in parts of machines not carrying the magnetic lines of force, and hence having requirements not different from ordinary machinery castings.

In electrical castings a permeability test used in conjunction with strength and hardness tests should be sufficient to define the quality of the material. Since permeability probably bears a fairly close relation to chemical composition it might be possible, although certainly less satisfactory, to specify analysis in place of permeability direct.

IV. Heat-resistant and Chemical-resistant castings.

A large variety of castings come under this head; the best known examples are probably ingot molds and grate bars. Only a few foundries are giving attention to producing castings of these special properties, and there is but little generally available information. Grate bars, for example, are ordinarily made of the cheapest possible mixture irrespective of its quality as regards service. In the case of ingot molds, on the other hand, some pains are taken to obtain the special quality of heat-resistance, and a low-phosphorus iron is always used for this purpose.

There are no tests for heat-resistance and chemical-resistance of cast-iron in common use. For heat-resistance it is a very difficult matter to devise any single test which will answer for all classes of castings, since the effects of heat are manifested in several different ways. Chemical analysis may be specified with advantage in some cases, since the melting-point of cast-iron depends chiefly on this factor. Resistance to the action of chemicals can be tested directly without much difficulty in a manner similar to the accelerated corrosion test used on steel. There is, however, great need for the standardization of all conditions under which such tests are made, so that comparable results may be obtained.

V. Chilled cast-iron car wheels.

These form one of the most interesting applications of cast-iron in American practice. The service conditions for these wheels are very severe. The load on each wheel often amounts to between **10.000** and **20.000** lbs. They are constantly subjected to heavy blows due to pounding at rail joints. The friction of the brakeshoes induces severe heat strains in the tread. Finally the users of these wheels demand that they have a high resistance to wear. Owing

to the nature of their service any failure is apt to be attended with very serious results, and hence great pains must be taken to insure a uniformly high quality of product.

The results desired are produced by the use of both special materials and special methods of casting. Formerly charcoal iron was used exclusively for this class of work, but now coke iron enters largely into the mixture. The problem of a high-grade mixture has been much complicated by the necessity of remelting the old wheels, with their usual high content of sulphur. A partial corrective for the excessive amount of scrap which it is often necessary to use is found in the addition of ferromanganese, and there have also been obtained some encouraging results through the use of ferrotitanium.

The special methods of casting consist in the use of a circular chill in that part of the mold forming the tread of the wheel. This method has been frequently described and needs no discussion. With the proper percentage of silicon this results in the tread being chilled to a depth of about $^3/_4$ in., back of which is tough grey iron. The chilled tread is, of course, intensely hard and exceedingly resistant to wear, while the wheel as a whole is very tough and has proven eminently satisfactory in service. Steel wheels, long used on passenger cars, have recently been substituted on freight cars of very high capacity They are, however, much more expensive and in some cases have not proven entirely satisfactory as to wear, so that there is every indication that the cast-iron car wheel will hold its own for a long time to come.

The specifications and tests required for car wheels have been so often published and are so readily accessible that they need not be repeated at length. Briefly summarized the tests are carried out on a certain number of the castings themselves, and consist chiefly of a drop test to measure the resistance to shock and blows, a heat test made by pouring molten iron around the tread of the wheel, to measure the resistance to heat strains, and measurements to verify dimensions. It would appear that a hardness test on the chill might advantageously be added, in view of the known variation in the hardness of chilled iron. A test for wearing quality would be better still, but no satisfactory test of this sort is in sight.

VI. Chilled rolls for rolling mills.

Cast-iron rolls still hold their own in sheet-mill and som other classes of finishing work, although cast-iron has been quite generally displaced by steel for the heavier service. In this case the service conditions are not unlike those to which car wheels are subjected, but they are even more severe as to heat strains. Moreover, owing to the great thickness of the castings the initial shrinkage strains are very great. The use of the very best grades of charcoal iron, together with air-furnace melting, is generally recognized as necessary for the successful manufacture of chilled rolls, chiefly on account of the difficulty with cracking due to heat strains. It is reported that the use of vanadium in chilled rolls is adding considerably to their wearing qualities.

For this class of castings there are no satisfactory tests in sight. It is inconceivable that any tests could be of value which are not made on the roll itself, and, while a difficult proposition, it is possible that in time a set of tests similar to those used on car wheels may be devised.

VII. Brakeshoes.

Brakeshoes may serve as an example of the many smaller specialities which are made of cast-iron. The requirements here are long life, with this limitation: that the hardness of the brakeshoe must be less than that of the wheel so that the wear will not be on the wheel. A close grain-structure is advisable, and in some cases at least is being obtained by the use of steel scrap in the cupola mixture.

For brakeshoes a wearing test used in connection with hardness limits would best define their quality. No satisfactory method of testing resistance to wear is in sight, but it would seem that specifications for hardness alone could be advantageously used pending the development of such a test

VIII. Cast-iron pipe.

In point of tonnage, pipes are probably the most important castings made in this country. Cast-iron is a particularly suitable material for pipes which are to be placed underground, on account of its relative resistance to corrosion as compared with steel and

other commercially available materials. Competition is keen in this line, so that low-priced iron is necessary. Within the limitations set by price, close grain and strength are desirable, while hardness must be kept within such limits as will permit of a small amount of machine work.

In regard to the properties of the metal, none of the present specifications for cast-iron pipe lay stress on anything other than strength as determined on a separately cast test-bar. A test for bursting strength and freedom from leakage made directly on the pipe would, of course, be a more accurate index of utility, but is probably too cumbersome for practical use. The transverse-strength determination is probably as satisfactory as any simple test could be, but might with advantage be supplemented by specifying hardness limits.

IX. Stoves and furnace work.

Malleable cast-iron and steel have been tried for stoves, but while they have perhaps a place, gray cast-iron has proved more satisfactory and has steadfastly held its own. The service requirements here are resistance to the action of heat, resistance to warping, and a certain degree of strength. However, as these castings are very thin and are frequently highly ornamented, a very fluid iron is essential, and in practice the service requirements are deliberately ignored to facilitate manufacture. Resistance to heat requires low phosphorus, and resistance to permanent expansion, which causes warping, demands low silicon, but both phosphorus and silicon are invariably carried high in this class of work, to increase fluidity and make it easier to produce perfect castings. However, the product of our stove foundries is fairly satisfactory in service, and in appearance and finish has reached a high degree of perfection.

Specifications for stove and furnace castings should include tests for strength, hardness (since many parts have to be drilled), and resistance to heat. There is no trouble in regard to the first two tests, but, as previously stated, no good method has yet been devised for gaging heat-resistant qualities. Specification of chemical analysis can be used with advantage, but cannot be regarded as a really satisfactory substitute for the much-needed direct test for heat-resistance.

There are of course innumerable other uses of cast-iron which might be described, but to make the catalog complete would be an interminable task. In conclusion the fact should be emphasized that in many cases it is not possible to do much in the way of formulating specifications on account of the lack of suitable methods of testing the properties. The apparent inclination of many users of castings to entirely ignore the quality of their material may be largely attributed to the lack of any definite numerical means of gaging quality.

TRADE TEACHING IN FOUNDRY PRACTICE AT WENTWORTH INSTITUTE.

BY MR. E. A. JOHNSON, WENTWORTH INSTITUTE, BOSTON, MASS.

Few fields of industrial activity and none of the great departments of the mechanical arts have been so slow as foundry work to appreciate and profit by the recent advances in the application of education to modern industry. This branch of manufacturing has long been behind the other branches in the industrial field in its development and even at the present time it is not uncommon to see methods used in American foundries that were proved to be inadequate and out of date several decades ago. But, speaking generally, manufacturers have awakened to this situation and to-day great strides are being made in the development of foundry practice. In many manufacturing plants new methods are now being adopted, new machinery is being designed, new standards are being established, all with a view to bettering foundry conditions and producing higher grade castings more expeditiously.

On all sides, however, one hears the complaint that the greatest difficulty in this forward movement is getting the *right kind of men* to carry out the new ideas and push forward the new work. In fact, in many cases this difficulty of getting men has been found so great that foundry managers have reluctantly been forced to abandon their plans for improvement and have been obliged to continue in the old and inefficient ways.

It has everywhere become apparent that the men trained in the old-fashioned way in the foundry are not open-minded toward changes and are inadequate for these new demands. The difficulties confronting nearly every manager who wishes to see his foundry advance as fast as the other great departments of manufacturing are many. He must first find some way of attracting the right sort of young men into the foundry business. Second, he must devise some kind of training which will make them both

more efficient and more open-minded toward improvements. Third, some way must be found, too, to give such men the right view-point and make them willing and anxious to co-operate with their employers in securing higher efficiencies for the plant. Fourth, they must also be given a broader outlook over the whole field of foundry practice than the old-fashioned foundry apprentice secured. And lastly, if these men are to be of the greatest

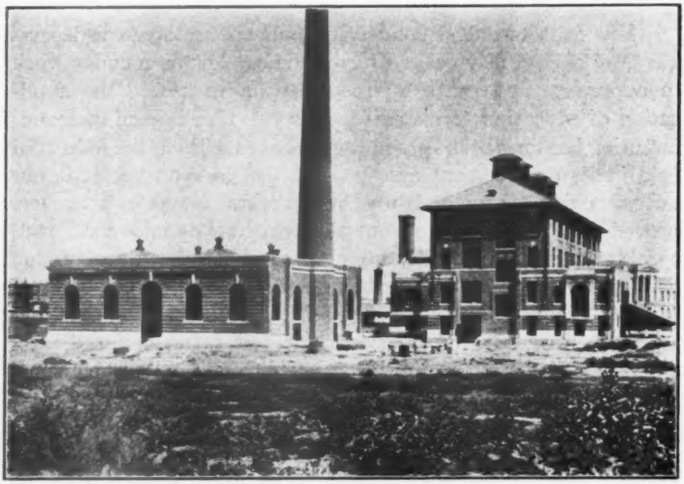


FIG. 1.—A VIEW OF THE INITIAL GROUP OF BUILDINGS, SHOWING POWER PLANT, STEAM AND ELECTRICAL LABORATORIES, OFFICES AND MAIN SHOP BUILDING.

service in advancing foundry methods, they must be given a practical scientific foundation upon which to build their work.

This problem of securing young men of the right kind with native intelligence and ambition, and of equipping them properly to help in this forward movement, is the most serious one confronting foundry managers to-day. It is perhaps more than all else responsible for the fact that foundry practice is to-day, on the whole, far behind the other great manufacturing trades.

In helping to solve this problem the trade school has been demonstrated to have great possibilities. It, better than any

other agency, can attract high grade young men; it can cultivate ambition and arouse enthusiasm for this important field of work; it can give the broad outlook and at the same time teach in a thoroughly practical way the rudiments of foundry work; and it can do more than this, because, while young, the man is being trained in practice and given an experience that does not differ from experience gained in commercial shops, he can be taught theory

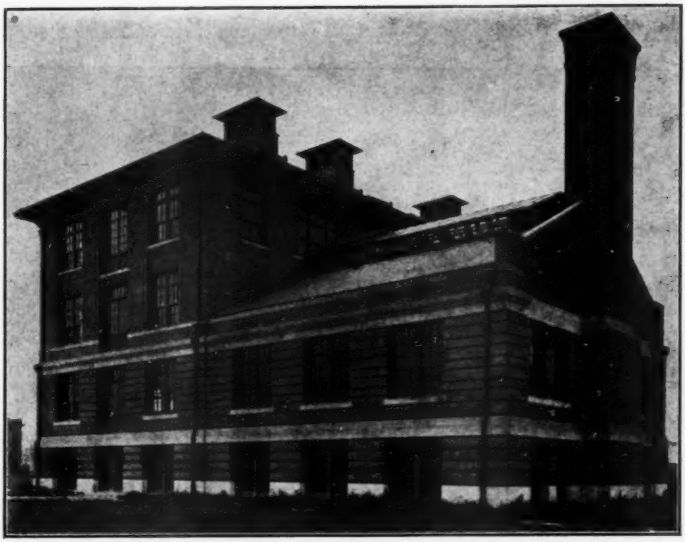


FIG. 2.—THE FOUNDRY.

and, without loss of time, be given a useful scientific training to serve as a foundation for his future commercial experience.

Fully appreciating all of these advantages possessed by trade-school teaching, and appreciating equally the need for intelligent and trained men in the foundry industry, the Directors of Wentworth Institute determined to devote a considerable portion of the trust funds that had been left in their charge to a department designed especially to teach modern foundry practice.

Before attempting to give a detailed account of this depart-

ment and of the courses of instruction in foundry work that have been offered to the public, it may be well to give a few words of description of Wentworth Institute as a whole.

Aim and Scope of Work.

The Institute was founded by Arioch Wentworth, a wealthy manufacturer of Boston, who stated in his will that it was his desire to establish a school "for the purpose of furnishing education in the Mechanical Arts."

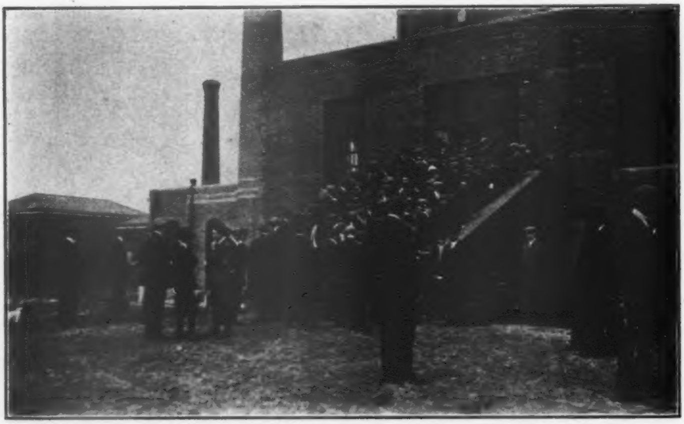


FIG. 3.—ON THE OPENING DAY THERE WERE OVER 1,700 APPLICANTS FOR DAY AND EVENING CLASSES.

The school was incorporated nearly eight years ago, and for several years the Board of Directors conducted a most careful study and investigation to determine the most suitable location for the Institute and the exact kind of educational work which it was wisest for it to adopt. Three years ago this fall, architects were appointed to carefully study the question of housing the school and they prepared a plan not only for the buildings which we now occupy but for a most comprehensive program of future development. From this it is evident that both the Board of Directors and the architects have realized the importance and the magnitude

of the work of training young men to adequately meet the demands of modern industry, and have realized that elaborate provision for buildings and equipment must be made. After these general one for the testing of properties of building materials; besides the usual lecture rooms and recitation rooms for class exercises. There is also a small wing extending to the south for the administration offices; and a power house about eighty feet square which also contains, besides the equipment used for furnishing heat, light and power for the Institute, a laboratory for steam power plant practice and a dynamo and motor laboratory.

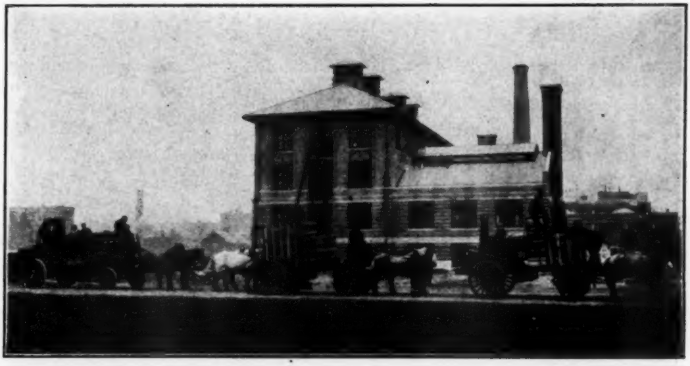


FIG. 4.—THE INSTALLATION OF EQUIPMENT WAS MADE A MOST VALUABLE FEATURE OF THE FIRST YEAR'S INSTRUCTION.

Fig. 1 shows a general view of these buildings with the power plans had been approved, the contract for the initial group of buildings was let in October, 1910. These buildings consist of the foundry and the main shop building which includes a large carpenter shop; a pattern shop—occupying the whole of the second floor, 146 ft. long by 50 ft. wide; a machine shop of equal size on the first floor; a blacksmith shop; a plumbing shop and a room for electric wiring; two large and well-lighted drawing rooms and an extensive laboratory for practical mechanics and plant in the foreground, and Fig. 2 shows a view of the foundry in the east end of the main shop building. Notice the chimney which contains the cupola stack in the picture on the left. It will

also be noticed that the foundry extends through underneath the end of the shop building on the first floor, giving it a total length of something over one hundred feet.

These buildings were completed just a year ago and were opened to receive earnest, ambitious young men eager for instruction within a few days of the date that the building was turned over to us by the contractors and before there had been time to install or arrange the equipment. The next two figures (Figs.

FIG. 5.—ONE OF THE EIGHT DAY TRADE CLASSES WHICH WAS STARTED AT WENTWORTH INSTITUTE IN SEPTEMBER, 1912.

3 and 4) are from photographs taken the same day and show students applying for admission on the opening date, and the equipment as it was being delivered outside our doors. From the very outset, therefore, the students were initiated into an atmosphere of honest industry, for it was our effort to get that equipment installed as promptly and as perfectly as it could be done by any crew of trained and experienced men. We chose for our workmen, however, boys who had had no experience.

Later on as the reader views other illustrations showing our finished equipment, he will be able to judge how well intelligence, right spirit, and careful planning were able to succeed.

The policy of the Board of Directors of Wentworth Institute is to adhere strictly to the plan of the founder, that is, to furnish education in the mechanical arts. Its aim is solely to train young men for efficiency in skilled trades. The instruction throughout, therefore, is designed to develop not only manual skill and dex-

FIG. 6.—UP-TO-DATE EQUIPMENT AND BEST COMMERCIAL METHODS STIMULATE INSTRUCTION.

terity, but also a comprehensive knowledge and understanding of the theory that goes parallel with each and every trade included in the curriculum, and it will be noticed as we describe the courses of study, especially as we describe the work in foundry practice, how carefully and how closely these two ideas of developing mechanical skill and of teaching the theory go hand in hand all through our work. In every department the training is sufficiently broad to develop the habit of reasoning, some power of initiative

and a sturdy honest ambition. Methods of instruction that give only a superficial knowledge, and a familiarity with only technical details of these trades, are invariably avoided. Instead, all the work in every course is based on the solid foundation of the scientific principles that underlie each. In this way it is the aim of Wentworth Institute to increase the average standard of skill and efficiency in all trades for which it establishes courses.

FACULTY.

It will probably interest you to hear briefly just a word of the character of the men who have been put in charge of this enterprise. Wentworth Institute is directed by Arthur L. Williston, a graduate of the Massachusetts Institute of Technology and a practical engineer with experience on one of the great western railroads, as well as a reputation as a teacher and educational organizer. He was at one time a member of the faculty of the College of Engineering of the Ohio University, a member of the commission which established the Carnegie Technical Schools in Pittsburgh and for twelve years was the head of the School of Science and Technology at Pratt Institute, Brooklyn—a school which has perhaps done more than any other in America to advance the kind of practical education that I am here to describe. The faculty that Mr. Williston has gathered around him to carry on this work also is composed of men of experience. For example: one man has had a marked success in one of the most successful trade schools in the Middle West, and another has been head of an industrial school in the South which attracted much favorable attention. Another had been conspicuous in organizing one of the leading technical high schools of the country and another had been in charge of one of the engineering laboratories in one of the great state universities of the Middle West.

I will not take the time to go through the entire list of teachers, but these illustrations are typical of the twenty-three men who now constitute the Faculty of Wentworth Institute. Fourteen have been employed as skilled mechanics or as foremen and superintendents in charge of practical work; four have been employed continuously in engineering offices; two more have had large experience in important manufacturing plants, and the remaining three have had continual contact with practical work during

their teaching experience. On the other hand, a great majority of them, including the practical men, have had some college or technical school training.

With a faculty containing such a large percentage of men of distinctly practical point of view, no one could fear that there is danger of the work ever becoming academic or being removed from commercial conditions.

FIG. 7.—EVERY BOY IS ASSIGNED A PRACTICAL TASK AND HELD STRICTLY TO A GOOD COMMERCIAL STANDARD.

The Method of Selecting Pupils.

We realize that the real success of our whole undertaking depends upon our ability to secure the right kind of boys to enter the various courses. A great deal of skill is required for their proper selection. We cannot use examinations, in the ordinary sense of the word, to determine the fitness of the applicants for the various trades, for it happens again and again that the boy who has not even finished the eighth grade in public school proves himself superior to others that have attended school for a longer time. We try to analyze each trade and determine the qualities of mind

and of character that are needed for success in each, and also the physical qualities that each requires. No infallible system has been invented for determining which boys have the needed qualities, but great care is taken nevertheless to determine this. Each applicant is required to have one, and sometimes two or three interviews with the principal of the school. After this, similar interviews are had with the heads of the several departments.

FIG. 8.—KNOWLEDGE OF THE BEST METHODS OF CLEANING AND FINISHING CASTINGS IS JUST AS IMPORTANT AS A GOOD KNOWLEDGE OF MOLDING.

In these interviews the same methods are used as would be used by the superintendent of a large manufacturing plant in selecting workmen for various departments in a long list of applicants, and we are obliged to judge by the eye, by the voice, by the manner, by the physique, by the previous experience, and by the extent to which previous opportunities have been, so far as can be judged, improved and made the most of. After such interviews, all boys

who do not show evidence of fitness for the particular kind of work they wish to undertake are advised to try something else, and when they do show promise of success and are accepted, they are accepted only for a period of trial. It is only by using this kind of extreme care, we feel that we may hope to accomplish the desired result.

In order to attract such men as will have real interest in the work and in order not to bar those who have ability but not means, a nominal tuition of $6 per term is charged, three terms constituting a year's work. For the evening courses the fee is even smaller. It is but $6 for the two terms which constitute the school year in these classes. This low tuition, though it does not prevent the interested boy from entering, is sufficient to keep out those who might apply through curiosity and with no real ambition to continue the work to its completion.

Courses of Instruction.

The courses of instruction which have thus far been offered in the initial group of buildings, already described, are of two quite different types: First, short one-year courses of *apprenticeship grade* intended for beginners and persons who have had little practical experience. Second, longer and more thorough courses intended for those who wish to become superior workmen, master-mechanics, superintendents, etc.

It would be interesting, if time permitted, to describe each one of these courses and to show the students at work in the different shops and laboratories. I should like, for example, to show a day class in carpentry with twenty-six or twenty-eight boys at work building a small cottage and then show you in connection with this the same group of boys in the planing mill of this department getting out the stock for their work, and later show the same class again in their applied science laboratory studying out the principles of the roof truss for the building they are at work upon in the shop. This would be interesting, I am sure, because it would show how nicely theory and practice at Wentworth Institute go hand in hand.

I should like also to show you the class in pattern-making (see Fig. 5), and show too the great variety of patterns and the intricate character of the work which the boys in this class turn

out; and I should like to show also in connection with this class, the means which their instructors have devised for teaching them in laboratory the principles of mechanism and the laws underlying machinery. You would be interested also in our splendidly equipped machine shop and in some of the things that the class in that department have already completed since the school was opened a year ago. See Fig. 6.

Another feature which always attracts the attention of visitors who go through our buildings is to see our class of plumbers

FIG. 9.—MODERN CORE-MAKING INVOLVES SO MANY PROBLEMS OF VITAL IMPORTANCE THAT IT REQUIRES A SEPARATE DEPARTMENT FOR ITS BEST DEVELOPMENT.

at work in the shop wiping joints or making traps, and then see a group of boys from the same class working in the special laboratory that has been prepared for them, testing the traps they have made for siphonage or studying the flow of water through different arrangements of piping. The other features which a visit through the buildings of the Institute would show include the electric-wiring shop where those who wish to go into the trade of wiring buildings get their training, the steam power plant laboratory

where those who wish to become stationary engineers get instruction and practice, the motor and dynamo laboratories where classes of young men who are preparing themselves for positions in plants where such apparatus is manufactured or extensively used get their fundamental training and experience. It would also show classes that work in the drawing room, for every group in the Institute, including those who are enrolled in the foundry department, receive instruction on the drawing board, not because we

FIG. 10.—A MECHANIC IS KNOWN BY THE EXCELLENCE OF HIS FINISHED WORK.

wish to make draftsmen of any of them, but because we have found by experience that they can work from drawings more intelligently if they know something about how drawings are made, and also because we find that through the eye boys take in many ideas more readily than they could in any other way.

I ought to add, too, perhaps, that there are in addition to these one-year and two-year day classes that I have given a brief glimpse of, sixteen or eighteen equally valuable evening classes

that are conducted for the benefit of those young men who are employed during the day and who cannot possibly attend the Institute at any other hour. *And*, if you will pardon just a single word of digression, I would like to call your attention to the eager and the earnest way in which the 520 men who attend these evening courses attack the tasks that are laid out for them three nights a week after they have finished their regular day's work. One would think that ten hours of continuous employment in

FIG. 11.—POURING SOME TYPES OF MOLDS REQUIRES CO-OPERATION AND DRILL.

the commercial shop would suffice them, but the opportunity to work where every point is made plain and where each night gives knowledge and added earning power, makes them surprisingly eager for more.

Course in Foundry Practice.

Having given you this brief glimpse of the aims of Wentworth Institute and of some of its principal courses, the reader will now be the more interested in a description of the foundry course and

its equipment because of the better understanding of the spirit of the work and the atmosphere and surroundings in which it is done.

Fig. 7 is a general view of the molding floor taken from a point in front of the cupola looking back toward the tool room and stock room and foundry office. The open floor space for molding is about 50 by 75 ft. and will easily accommodate a class of from fifty to sixty students. The reader will notice the gallery which gives us a second floor over almost the entire shop and yet leaving sufficient opening for light and ventilation and for the operation of the overhead traveling crane through the center-bay. Some may have noticed, too, in the general view of the foundry which showed in one of the first figures, the monitor roof and overhead lighting which gives us almost ideal conditions of light and ventilation.

Fig. 8 shows a group of boys at work in the cleaning room containing the tumbling mill and emery wheel, and benches which are used for hand cleaning. It is intended to install here pickling trays and sand-blast equipment in the near future. The next view, Fig. 9, shows the core making department in the gallery of one side of the shop. The brass molding department and the brass furnaces are on the other side of the shop, and I want to call special attention to these brass furnaces, not because of anything so very remarkable in themselves, yet I am sure the details of their design and construction would be of interest if they could be seen, but because these furnaces were designed in our own foundry. The drawings were made by our students and the methods of construction discussed, patterns were finished in our pattern-making department; the castings, too, are our own product and the machining was done in our own machine shop, and were assembled, installed and lined by our own boys; and in describing in detail in this way this particular piece of equipment, I do not want to give the impression that it is an exception. Practically everything in our equipment has been built or installed in just the same way. There are some persons who profess to believe that high grade practical work of commercial quality cannot be done by students in the trade school, but if they could see just how a job of this sort was planned and executed, they would appreciate the very many advantages the conditions pre-

FIG. 12.—SYSTEM AND ORDER ARE ESSENTIAL IN A FOUNDRY.

vailing in the trade school have over those found in the most favored commercial shops for executing projects of this kind. Fig. 10 shows a variety of completed small castings, and Fig. 11 shows a group of students pouring a mold. Fig. 12 is another illustration of student planning and student construction which will be of interest to many practical men. It shows one corner of the tool room in our foundry which is an example of not only

FIG. 13.—A DAY'S OUTPUT DEPENDS UPON THE MAN'S SPIRIT AND KNOWLEDGE AND THE EFFECTIVENESS OF HIS EQUIPMENT MORE THAN IT DOES UPON HIS PHYSICAL STRENGTH.

student construction but class planning, and I would like to leave it to the gentlemen present to tell me how many of the practical molders in their employ would make a better job of a problem of this kind were it left for them to solve. I think I can see some of them shake their heads when I ask if they think that their superintendents would do better.

As other illustrations of the same idea, I would be glad to

show some aluminum match plates planned and made by our boys. These are not especially unusual, but I refer to them because the design and construction of labor-saving devices of this sort for the rapid duplication of work all form a very important feature of the instruction in the courses. The benches for snap-flask molding at Wentworth Institute, also designed and built by our students, have some novel features that would also perhaps be of interest.

FIG. 14.—TRADE SCHOOL INSTRUCTION SHOULD INCLUDE A WIDE RANGE OF PRACTICAL WORK.

I have shown sufficient to indicate, I think, something of the variety and the scope of the work that we have accomplished in the first nine months that the foundry of Wentworth Institute has been in operation. I am sorry that I do not happen to have any photographs that would indicate the volume of the output which our boys are capable of producing in a single day, but at the time that Dr. Moldenke's invitation was received, the foundry

FIG. 15.—A CASTING MADE BY STUDENTS IN THE FOUNDRY AT WINONA INSTITUTE. THIS ILLUSTRATES SOME OF THE POSSIBILITIES OF TRADE SCHOOL INSTRUCTION.

had closed for the year and it was too late to obtain them. I happen to have, however, a couple of photographs of work done at the foundry of the Winona Technical Institute under my own direction which will perhaps serve to illustrate this point just as well. The first one, Fig. 13, shows a day's output for a single boy on molds made from the motor head pattern shown on one of the molds in the foreground. These are complicated patterns to mold and, if I remember rightly, there were in this boy's

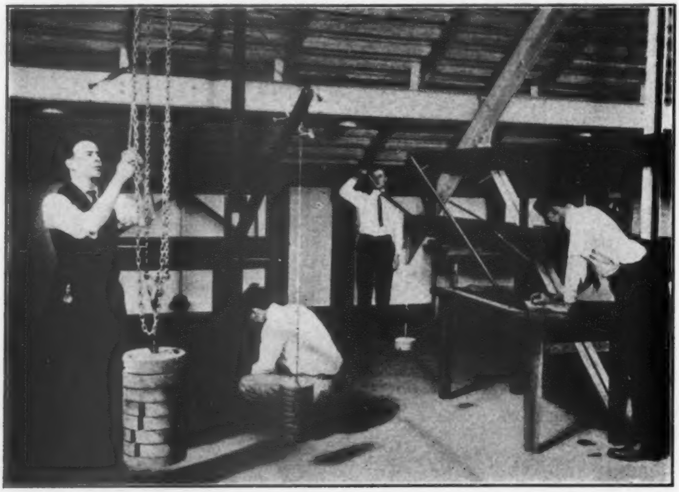


FIG. 16.—THE PRINCIPLES OF PRACTICAL MECHANICS FIND DAILY APPLICATION IN EVERY FOUNDRY.

floor ten molds of this pattern, besides two molds in the background contain two saw arbor bearings.

Perhaps some will say that these are excellent examples of small work, but that the trade school is not practical when it comes to heavy work or an intricate line of work. I would like to call the attention of any such persons to the molding of a $16\frac{1}{2}$-ft. flywheel.

Fig. 14 shows the lower half of the hub in the sand and the web cores being set. Fig. 15 shows the finished casting exactly

FIG. 17.—AN ACCURATE USABLE KNOWLEDGE OF THE PRINCIPLES OF CHEMISTRY IS ESSENTIAL IN EVERY DEPARTMENT OF MODERN FOUNDRY PRACTICE.

FIG. 18.—AN ACCURATE KNOWLEDGE OF THE PHYSICAL PROPERTIES OF FOUNDRY PRACTICE IS LIKEWISE ESSENTIAL.

as it was lifted from the sand without any brushing or cleaning. The arms in this casting are tubular, onto which were cast the hub and the web, and the splitting of the hub and the web was complicated because of the arms crossing each other. As a whole the molding and casting of this job was difficult and yet was accomplished by students.

FIG. 19.—THE GRADUATES FROM SIX ONE-YEAR DAY TRADE CLASSES, JUNE, 1912.

Instruction in Related Branches.

In what I have been thus far describing, I have been referring exclusively to the instruction in shop practice. Parallel with this, however, goes the course of lectures and practical talks on modern foundry practice and labor-saving methods, and the instruction in mechanical drawing and design of foundry appliances similar to the corresponding courses given in all the other trades in Wentworth Institute. There is also instruction in practical mechanics, dealing with forces, conditions of equilibrium,

work, energy, power, etc., Fig. 16, and instruction in power plant operation, and besides these I have saved until the last the description of the two courses which I believe make the Wentworth Institute course in foundry practice the most valuable and the most unique. The first of these courses is given in foundry chemistry, and Fig. 17 shows our foundry testing laboratory where our foundry students are taught to make every day practical

FIG. 20.—GRADUATES FROM THE FOUNDRY CLASSES —A GROUP OF EARNEST, WELL-TRAINED MEN.

chemical tests of all the foundry productions and foundry materials, which you gentlemen know is absolutely essential to both genuine progress and the highest grade of work. Fig. 18 shows the corresponding laboratory, also closely adjoining our foundry department, where our foundry students are taught to make every variety of physical test on the product of every heat.

I have, I fear, already overtaxed your patience, and yet in spite of this I have been able to but touch the high spots; the

work is new, it has been in operation but nine months, but even this short time indicates possibilities that are most far reaching and which, even before a single generation has passed, may profoundly influence the business in which you gentlemen are interested.

But if these results are to be accomplished, we need the help and the co-operation of every one in the foundry business. You can help us in many ways. You can send to us the right kind of raw material to be trained. You can help us with advice and practical suggestions in many ways. You can help us by finding suitable employment for the young men whom we have trained and you can help us by spreading abroad the notion that the best opportunity and the best chances for advancement in the foundry industry are only open to those who have made themselves well prepared to deal intelligently with the more and more perplexing problems of a fascinating but complicated business.

Wentworth Institute has made a large investment in this enterprise for the benefit of the foundry industry and it is done with the expectation and full confidence that those vitally interested in the industry will be glad to co-operate in these directions.

The next photograph, Fig. 19, shows the graduating class at the end of the first year's work at Wentworth Institute and Fig. 20 shows twenty of the twenty-three men to whom last year we granted certificates for the satisfactory completion of our first year work in foundry practice.

In conclusion, I would ask you to look into the faces of these young men and see if you do not find there evidence of the type of intelligence and the spirit of loyalty and co-operation that each of you would like to see more generally represented in your own works.

STRUCTURE OF GALVANIZED IRON.[1]

BY ARTHUR WALKER AND WILLIAM H. WALKER,
Research Laboratory of Applied Chemistry, Massachusetts Institute of Technology, Boston, Mass.

Galvanized iron, by which term in this article we shall include all zinc protected iron, consists not of a sheet of iron covered with a layer or skin of pure zinc, as one might expect, but, on the contrary, of a complicated system of iron-zinc compounds, starting with pure zinc on the outside and passing through these

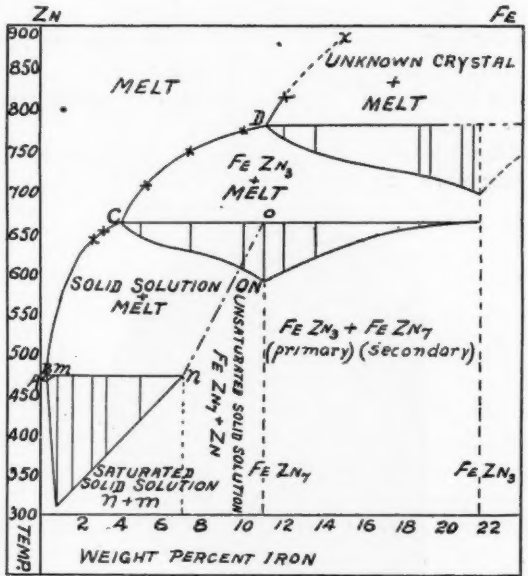


FIG. 1.

[1] Reprinted from *Journal of Industrial and Engineering Chemistry*, Vol. 4, No. 6, June, 1912.

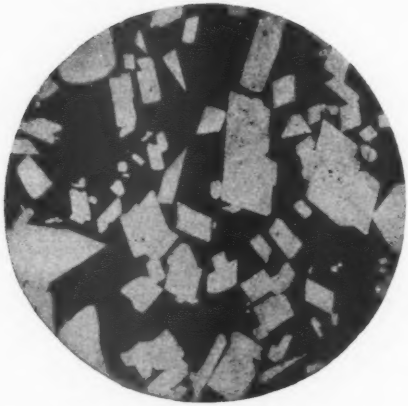


PLATE 1.

alloys to the iron base within. We shall consider the structure of zinc protected iron under the three heads:

1. Hot galvanized—material made by passing the iron through a bath of melted zinc.

2. Sherardized—the article heated in the presence of finely divided zinc and zinc oxide.

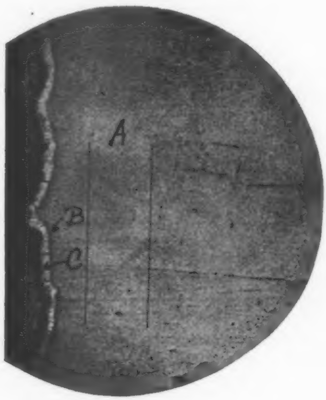


PLATE 2.

3. Wet or Electrogalvanized—a layer of either zinc or a zinc alloy deposited electrolytically on the iron article from an aqueous bath.

By examining the zinc-iron alloy diagram constructed by v. Vegesack,[1] which is reproduced in part as Fig. 1, we see that by raising the temperature iron will dissolve in melted zinc to at least 24 per cent. Beyond this point it is impossible to go, owing to the volatility of the zinc. Hence the composition of the crystals separating along the dotted line DX is not accurately known, and will, for want of a better name, be called "binding alloy." From the molten mass at this point, crystals of this "binding

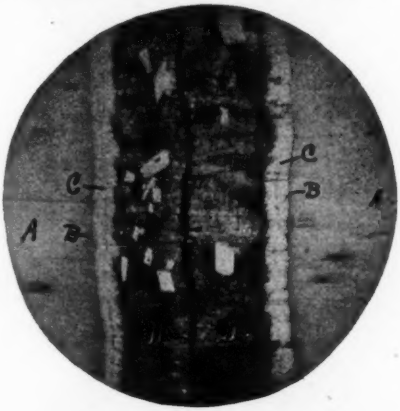


PLATE 3.

alloy," $FeZn_3$, $FeZn_7$ (or a more or less saturated solution of zinc in $FeZn_7$), separate on cooling, the nature of the primary alloy depending on the concentration. The point *n* on the diagram represents the maximum solubility of zinc $FeZn_7$ and it is probably this saturated solid solution which is noticeable in certain sections of galvanized iron. A fraction of one per cent (0.5–0.7 per cent) of iron remains dissolved in the zinc after solidification.

Hot Galvanizing.—Consider first the ordinary method of galvanizing with reference to the equilibria indicated above. A

[1] v. Vegesack, *Zeit. anorg. Chem.*, 52, 30 (1907).

PLATE 4.

piece of iron dipped into melted zinc at once begins to dissolve, the amount of solution depending on the length of time the iron is in the bath. As the solubility of iron in zinc is very low at this temperature the zinc bath soon becomes saturated, and a separation of the solid solution represented by the point *n* occurs. This crystalline compound is the "hard dross" of the galvanizer's

PLATE 5.

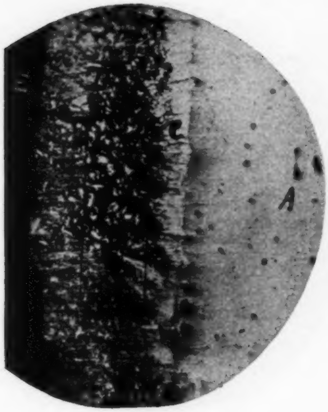


PLATE 6.

bath and is shown in the photograph, Plate 1. There is also a tendency for equilibrium to establish itself on the surface of the iron, and as at this point of contact between molten zinc and solid iron all possible concentration may be considered to exist, the specific properties of the individual crystals determine the character and amount of each constituent. The actual behavior

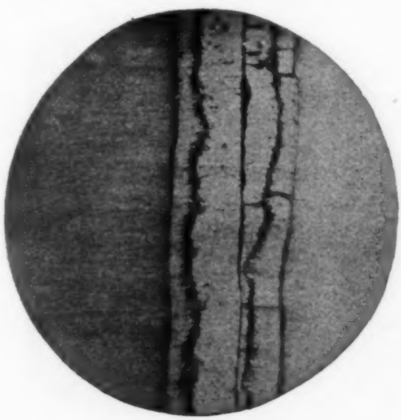


PLATE 7.

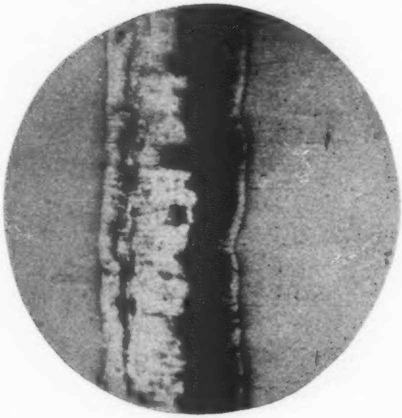


PLATE 8.

under varying conditions is best shown by microphotographs of the galvanized plates viewed in cross sections.

The preparation and polishing of plates in cross sections presented some difficulties, the chief of which lies in the tendency of the zinc to "flow" in polishing, and the ease with which it gives rounded or "burred" edges when cut at right angles. To

PLATE 9.

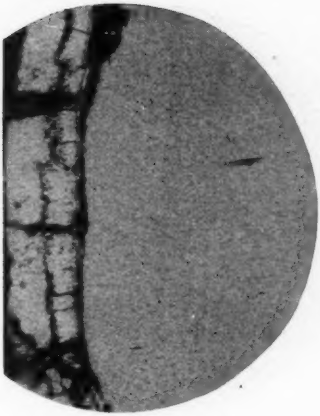


PLATE 10.

prevent "burring" several strips of the iron were immersed in sodium silicate solution until the surfaces were thoroughly covered, clamped tightly together in a small hand vise and dried for about two hours at 100° C. The hardened sodium silicate served to fill out the interstices resulting from the unevenness of the galvanized iron surfaces, thus preventing the burring of the edges at

PLATE 11.

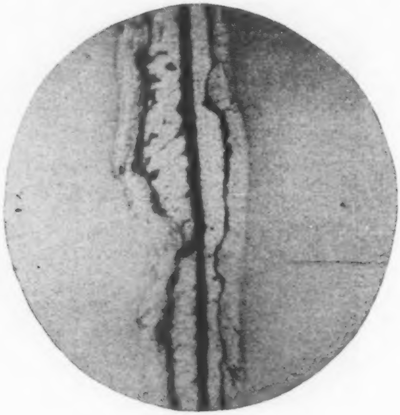


PLATE 12.

such points and the filling of such spaces by zinc and iron particles in cutting and polishing. After the sodium silicate had thoroughly hardened, the edges of the pieces were all cut to the same plane by means of a fine file, the final strokes being made in alternate directions so as to prevent any flowing of the zinc. The file was followed by fine emery paper, and this by still finer emery paper

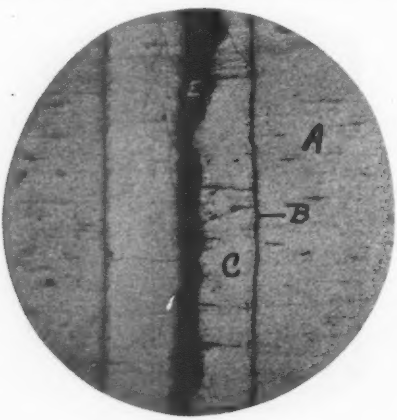


PLATE 13.

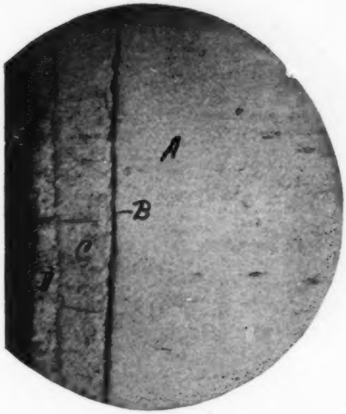


PLATE 14.

until the edges presented an unscratched surface to the unaided eye. The final polishing was done on soft cotton flannel, mounted on a piece of rubber, and covered with jeweler's rouge. In order to secure the best results, the final strokes were made very slowly and with a light pressure and always in alternate directions: 0.5 per cent nitric acid in 95 per cent alcohol was used as an etching

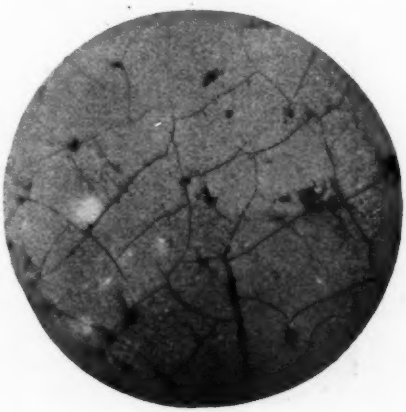


PLATE 15.

PLATE 16.

reagent. By means of a micrometer eye piece the thickness of the various layers found in the etched specimens was measured. Each division of the scale shown in certain of the photographs represents 0.072 mm. on the specimen. Plate 2 shows a section of ordinary hot galvanized iron in which A is the iron, B a very thin layer of the "binding alloy" of undetermined composition, C the compound $FeZn_3$, D the zinc layer which is filled with tiny crystals

PLATE 17.

of $FeZn_7$, not visible in the photograph, and finally the sodium silicate. Plate 3 shows a section of heavily galvanized iron in which, because of a longer period of immersion in the zinc bath, much larger crystals of $FeZn_7$ have formed. The large increase in the amount of the compound $FeZn_7$ due to abnormally long immersion in the zinc bath is shown in Plates 4 and 5.

That the tiny crystals of $FeZn_7$ are always present in the outer zinc layer can be determined in another way. If an ordinary galvanized plate is cautiously treated with caustic soda it is possible to dissolve the zinc without affecting the compound.

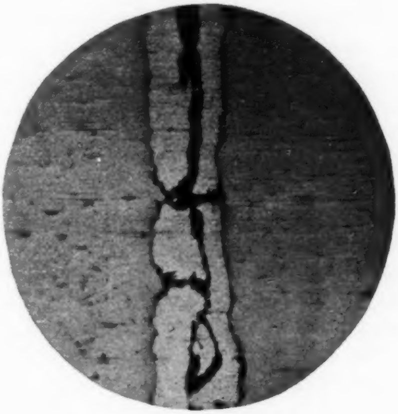


PLATE 18.

On a surface prepared in this way the tiny needle-like crystals of the compound become visible against the darker polygons of zinc.

Plate 6 is a cross section of a piece of galvanized pipe used and left by the French at Panama. It is remarkable that after an exposure of some thirty years there should still remain so unusual a coating of zinc. The layer of alloy $FeZn_3$ is also very heavy and the zinc is full of small crystals of $FeZn_7$, both facts indicating that the pipe was immersed for a considerable length of time in the galvanizing bath, and that the bath was fully saturated with $FeZn_7$.

Plate 7 is two pieces of ordinary galvanized iron, one very irregular in thickness, which have been so etched as to bring out more strongly the binding alloy B.

We have already corrected[1] a statement erroneously made by one of us[2] that these alloys were electronegative to iron. While not so electropositive as zinc, they are *not* electronegative, and hence afford a distinct protection to the iron base. Plate 8 represents two parts of a galvanized sheet which had been exposed to the weather for a number of years. The left side is from a spot which showed no corrosion, and exhibits a continuous layer of zinc on the alloy $FeZn_3$. The right side was selected from a spot very close to where corrosion of the iron had already commenced. Only the alloy is left and this is broken through at one or two points. Plate 9 shows two sections of heavily galvanized iron which had been allowed to rust in a damp place, but which have not been artificially etched. A is the rusted iron surface. B is a strip of iron surface next to the alloy which has been protected from corrosion by the electropositive character of the alloy. C is the alloy and D the zinc.

A property of galvanized iron with which all users are familiar is its tendency to crack and peal off when sharply bent. Investigation of cross sections made of specimens which had been bent showed that the parting of the galvanized coating from the iron takes place at the surface of the "binding alloy." This is as would be expected, inasmuch as the high iron alloys are very brittle. Such a break is shown in Plates 10 and 11.

Another property of galvanized iron is that of blistering with subsequent "flaking off" when heated, such, for example, as is seen on the flue of a house furnace. It was at first thought that the phenomenon was due to oxidation, but experiments carried on in an atmosphere of hydrogen and also carbon monoxide showed that this flaking occurred when the galvanized article reached a temperature of 360° C., or thereabouts. A polished section shows that in this case the parting takes place between the zinc and the alloy $FeZn_3$. Plate 12 shows such a structure. The black space between the alloy and the zinc is sodium silicate which has flowed in between the two layers.

[1] Patrick and Walker: This Journal, 3, Nov. 4 (1911).
[2] Walker: Proc. Am. Electrochem. Soc.

Sherardized Iron.—The material known as sherardized iron is not a definite structure, but differs according to the temperature, time and composition of the zinc-powder mass employed. When the zinc powder is diluted with inert material, such as silica, and the time relatively short, the coating will consist of a very thin layer of the alloy $FeZn_3$, together with a more or less distinct layer of binding alloy of unknown composition. If the time is increased, and the powder richer in metallic zinc, a heavy coating is obtained as shown in Plate 13. If continued long enough, a layer of zinc forms on the surface of the alloy as shown in Plate 14. In all sherardized coatings are to be seen many cracks running through the alloy. This is particularly shown in the upper part of Plate 13. By polishing a section at right angles to the cross section, Plate 15 is produced. This shows the alloy to be broken into numberless fissures much resembling mud cracks. It is probable that greater study of etching methods would bring out still other alloys in this complicated structure. Thus Plate 16 shows two sherardized sections which have been etched by slow rusting in the air. They are from the same sheet as that used in Plate 13, and show a second alloy between the main coating and what we have called the binding alloy. The blotched portions are the iron surfaces spotted with rust flecks. Owing to the brittleness of the main alloy a regular outline at the sodium silicate surface is difficult to obtain.

Electrogalvanized Iron.—The metal deposited by an electric current depends upon the impressed voltage and the composition of the electrolyte or bath. A coating of very pure zinc may be produced, or an alloy of widely varying proportions of iron may be obtained by adding iron salts to the bath, or, as is sometimes erroneously done, by using an iron anode. In any case a very thin binding alloy next to the iron is always to be seen. Plate 17 shows a piece of ordinary wet galvanized iron in which the coating D is pure zinc. E is the sodium silicate layer, and B the binding alloy. Plate 18 shows two pieces of such iron which have been bent before mounting. The coating is seen to have parted from the iron base along the line formed by it and the alloy.

PROCEEDINGS OF THE SEVENTEENTH CONVENTION OF THE ASSOCIATION.

BUFFALO, N. Y., SEPTEMBER 24-26, 1912.

The Seventeenth Convention of the American Foundrymen's Association was called to order in the Banquet Hall of the Hotel Statler, Buffalo, September 24, 1912, at 10 A.M., by the President, Major Joseph T. Speer.

THE CHAIRMAN:—Gentlemen, I have the honor this morning to introduce to you the Honorable Louis P. Fuhrmann, Mayor of the City of Buffalo, who is here to welcome the American Foundrymen's Association, the Institute of Metals, and the Foundry Foremen's Association. [Applause.]

MAYOR FUHRMANN:—Mr. President and Members of the Allied Foundrymen's Association: I am glad to come here this morning and give you a hearty welcome to the City of Buffalo. I was accorded a great privilege last night in being permitted to participate in the opening of the splendid exhibition which is now going on at our remodeled Broadway Arsenal, and I am glad that that great exhibit was brought to Buffalo in the year 1912, for 1912 is a great year in Buffalo and we are doing great things, and I believe that you know—I almost know that you know—that the City of Buffalo is a great city from any point that you may view it. It is great historically; the city of Millard Fillmore and of Grover Cleveland; the city of the great Free Soil Convention of 1848, and the Pan-American Exposition, which you all remember. It is a great city industrially, with a larger diversity of manufacturing industries than any other city on this continent. It is a great city racially, composed of all the nationalities of the globe, Italians, Poles, Irish, Germans and Americans—all living together in peace and goodwill, feeling that there's plenty of room in our great city for all of us and for thousands and tens of thousands more like us just as soon as we can attract them here. But above all these things, Buffalo is a great city because of the splendid

character of its people—you will observe that. Now, this is the city, gentlemen, that welcomes you this morning. We want you to stay with us just as long as you can, and when you return to your homes, we want it to be with the friendliest feeling toward our city and our people. [Applause.]

THE CHAIRMAN.—Gentlemen, I take pleasure in introducing to you the President of the Buffalo Chamber of Commerce, Mr. Orson E. Yeager. [Applause.]

MR. YEAGER:—Mr. President and Members of the Allied Foundry interests: The Buffalo Chamber of Commerce, which is the fourth largest in point of membership in the world, welcomes you to Buffalo. We appreciate the high position you occupy in the industrial life of the nation and we want you to realize Buffalo's advantages and the future that is assured us, particularly in your line. The last census shows an increase in the foundry and machine products of Buffalo of 104 per cent. With the completion of the Barge Canal and the improvements now being made in our transportation and terminal facilities, we feel that our progress will continue, not only in your industry, but in all other lines. We are glad to have you with us. We feel honored by your visit and we hope that your stay with us will be both pleasant and profitable and that you will soon want to come back again. [Applause.]

THE CHAIRMAN:—I would like to ask Mr. Alfred E. Howell, of Nashville, one of our vice-presidents, to respond to the two gentlemen who preceded him. [Applause.]

MR. HOWELL:—Mr. President, Mr. Mayor, Mr. Yeager, President of the Chamber of Commerce of Buffalo, and Gentlemen: It is indeed an honor to be welcomed by you and I also feel that it is an honor to belong to a body of men who, in my opinion, are the exemplars of the greatest on earth. In the South, we have a great many men who are complacently wealthy, they let their money out at five or six per cent and they themselves do nothing. We constitute a body who make the great pay-rolls that support the hundreds of thousands of well-meaning and hard-working men, and I think the man who produces the pay-roll is worth many times more than the man who simply draws interest. [Applause.] Being from the South, I naturally have more or less inclination to run to southern jokes. Major Speer—this is the second time

he's been guilty of the offense of calling upon me suddenly, without preparation—reminds me of an old darkey preacher in the South; he couldn't read himself, but he was a powerful good exhorter, and when he undertook to occupy the pulpit, he would open the Bible and run his finger along the line, and had another fellow down under the pulpit who would call out the words for him and then he would repeat them. They started off and the fellow down below said, "And the Lord said unto Moses," and he repeated, "And the Lord said unto Moses," "call my people," and he repeated, "call my people," meantime running his finger across the page. "Don't move your finger so fast," the fellow down below called out, and he repeated, "Don't move your finger so fast." "Now you've played the devil," said the fellow under the pulpit. "Now you've played the devil," repeated the exhorter. [Laughter.] So, while not intending to quote Scripture, I feel that when you call upon people without giving them any notice, that you have, in a sense, played the devil.

Gentlemen, it is a pleasure to be in Buffalo; it is a pleasure to be together, and when I look—and I am sure that his Honor the Mayor and Mr. Yeager feel that way when they look upon a body of men like this—I may not think there's any one man who knows more than anybody else, but there's some man in this audience and amongst the visitors to this Convention who knows things that nobody else knows, and we can all learn from them, and it is our object, in visiting your city, not to instruct so much as it is to mix with those who are well informed and those who know more than we do, and profit by the association. We thank you gentlemen extremely for your cordial reception and we hope to enjoy ourselves and believe we will. We are sure that the meeting will be all too short. [Applause.]

The Chairman:—I am going to leave it to you gentlemen individually whether I did play the devil or not. [Laughter.] I don't think, gentlemen, that we should close this joint session until we have had at least a word from two men who have done so much to bring our Convention to Buffalo. One of the good people who has been at work night and day is a bothersome sort of a person, but he was on the job. You all know him. He started with a little hand satchel in Pittsburgh and he had medals with a big buffalo on them from about eighteen inches in diameter to

a size so small that you could hardly see it, and every man, woman and child in Pittsburgh had one of those badges. We even see them to-day being worn as stickpins. I want to call on Mr. Frank W. Tracy, of the Chamber of Commerce. [Applause.]

MR. TRACY.—Mr. President and Gentlemen: "And Satan came also;" in other words, the Major has played the devil twice in the same place. [Laughter.] I made it a rule a long time ago to practice on anybody who would let me, and for that reason you notice Major Speer called on me for only just a few words. But to those of you who are not familiar with the history of securing this Convention, I will say that the Buffalo Chamber of Commerce and its Convention Bureau, have been at work very persistently since February 1, 1911, which makes it about nineteen months, for this particular moment; and you will have to excuse the very humble representative of the Convention Bureau of the Buffalo Chamber of Commerce for feeling very proud and happy, now that we have achieved what we started out to attain nineteen months ago. In this work, the Convention Committee has had the heartiest support of not only every officer of the Buffalo Chamber of Commerce, but of every city official. It became necessary, in order to make all of the various interests happy, to reconstruct our Convention Hall at a cost of between $160,000 and $175,000. We are indebted to you, gentlemen, because, without this incentive, we probably would not have the Convention Hall that we enjoy to-day. But, leaving the exhibition out of it entirely, we have represented before us this morning three large factors in our industrial life to-day. You, who have studied Buffalo, know what Buffalo has to offer to your particular industry. Before you leave, you will realize what we have to offer as a residence city—health and happiness. We want you and those who are here with you to absorb so much of Buffalo's happiness and good-will and good nature that you will want to come again, and when you go back you will want to tell others what a beautiful city Buffalo is for conventions, for business, and for home life. His Honor the Mayor omitted to give you the key to the city, but he is a pretty good Mayor and I can borrow it any time you want it and I am going to turn it over to my very good friends, Mr. Seaman and Mr. McFadden (the latter otherwise known as Tracy the Second), who were so instrumental at Pittsburgh in

securing this Convention for Buffalo, that I can't forget them, and before this week is over, something is going to happen. [Laughter.] Now, gentlemen, we want you to get busy and get all there is at your disposal. The Buffalo Committee have stood by the Chamber of Commerce in this undertaking and have provided royally for your entertainment. Don't overlook a thing that has been provided for you. If you lack anything, if there's anything that troubles you, if you want anything, ask anybody, and if they don't know, ask me, and I will try and be on the job. [Applause.]

The Chairman:—Gentlemen, as far as the joint session is concerned, we will now adjourn, but I would like to have all the members of the American Foundrymen's Association remain and we will carry out the program of that Association for the morning. Before adjourning the joint session, however, I would like to call on Mr. Miles, Chairman of the Local Committee.

Mr. Miles:—Gentlemen, I have been doing my share, with the other local foundrymen, in helping the Chamber of Commerce to get this Convention. I will say, however, as Major Speer explained, that I worked with Mr. Tracy, and we have all been hanging to his coat tails, rather than pushing him along. I returned from Europe last spring, about the time the Convention was being held in Pittsburgh, and was told that I was elected chairman of the local committee to go down to Pittsburgh and assist in obtaining the Convention for the City of Buffalo this year, and we went down there. Before this time I didn't know Mr. Tracy, and when I arrived there, I was handed a handful of badges to pin on everybody the same as Mr. Tracy did; I was told to stick them on and say, "You are it;" and we got enough "its" with the assistance of certain active individuals in Pittsburgh, to get you here. As representing the foundry industry of Buffalo, I extend a cordial welcome. We are very glad that you are here, and we hope that during your stay you will visit the plants of our local companies. I represent the Buffalo Foundry and Machine Company and I am sure we will be glad to have you come and visit cur plant, and there are other plants in other lines, especially very large plants in the steel casting line. Ours is a large foundry for making large work. There are large brass foundries, and I believe you will find it of interest to visit them. We have not made any itinerary for visiting the local plants, because we thought

a size so small that you could hardly see it, and every man, woman and child in Pittsburgh had one of those badges. We even see them to-day being worn as stickpins. I want to call on Mr. Frank W. Tracy, of the Chamber of Commerce. [Applause.]

MR. TRACY.—Mr. President and Gentlemen: "And Satan came also;" in other words, the Major has played the devil twice in the same place. [Laughter.] I made it a rule a long time ago to practice on anybody who would let me, and for that reason you notice Major Speer called on me for only just a few words. But to those of you who are not familiar with the history of securing this Convention, I will say that the Buffalo Chamber of Commerce and its Convention Bureau, have been at work very persistently since February 1, 1911, which makes it about nineteen months, for this particular moment; and you will have to excuse the very humble representative of the Convention Bureau of the Buffalo Chamber of Commerce for feeling very proud and happy, now that we have achieved what we started out to attain nineteen months ago. In this work, the Convention Committee has had the heartiest support of not only every officer of the Buffalo Chamber of Commerce, but of every city official. It became necessary, in order to make all of the various interests happy, to reconstruct our Convention Hall at a cost of between $160,000 and $175,000. We are indebted to you, gentlemen, because, without this incentive, we probably would not have the Convention Hall that we enjoy to-day. But, leaving the exhibition out of it entirely, we have represented before us this morning three large factors in our industrial life to-day. You, who have studied Buffalo, know what Buffalo has to offer to your particular industry. Before you leave, you will realize what we have to offer as a residence city—health and happiness. We want you and those who are here with you to absorb so much of Buffalo's happiness and good-will and good nature that you will want to come again, and when you go back you will want to tell others what a beautiful city Buffalo is for conventions, for business, and for home life. His Honor the Mayor omitted to give you the key to the city, but he is a pretty good Mayor and I can borrow it any time you want it and I am going to turn it over to my very good friends, Mr. Seaman and Mr. McFadden (the latter otherwise known as Tracy the Second), who were so instrumental at Pittsburgh in

securing this Convention for Buffalo, that I can't forget them, and before this week is over, something is going to happen. [Laughter.] Now, gentlemen, we want you to get busy and get all there is at your disposal. The Buffalo Committee have stood by the Chamber of Commerce in this undertaking and have provided royally for your entertainment. Don't overlook a thing that has been provided for you. If you lack anything, if there's anything that troubles you, if you want anything, ask anybody, and if they don't know, ask me, and I will try and be on the job. [Applause.]

THE CHAIRMAN:—Gentlemen, as far as the joint session is concerned, we will now adjourn, but I would like to have all the members of the American Foundrymen's Association remain and we will carry out the program of that Association for the morning. Before adjourning the joint session, however, I would like to call on Mr. Miles, Chairman of the Local Committee.

MR. MILES:—Gentlemen, I have been doing my share, with the other local foundrymen, in helping the Chamber of Commerce to get this Convention. I will say, however, as Major Speer explained, that I worked with Mr. Tracy, and we have all been hanging to his coat tails, rather than pushing him along. I returned from Europe last spring, about the time the Convention was being held in Pittsburgh, and was told that I was elected chairman of the local committee to go down to Pittsburgh and assist in obtaining the Convention for the City of Buffalo this year, and we went down there. Before this time I didn't know Mr. Tracy, and when I arrived there, I was handed a handful of badges to pin on everybody the same as Mr. Tracy did; I was told to stick them on and say, "You are it;" and we got enough "its" with the assistance of certain active individuals in Pittsburgh, to get you here. As representing the foundry industry of Buffalo, I extend a cordial welcome. We are very glad that you are here, and we hope that during your stay you will visit the plants of our local companies. I represent the Buffalo Foundry and Machine Company and I am sure we will be glad to have you come and visit cur plant, and there are other plants in other lines, especially very large plants in the steel casting line. Ours is a large foundry for making large work. There are large brass foundries, and I believe you will find it of interest to visit them. We have not made any itinerary for visiting the local plants, because we thought

that perhaps the members of the different associations would prefer to go as their time allowed. On our entertainment committee we have a very active and efficient man, Mr. Baird, president of the Buffalo Union Furnace Company, who has done much, as you will see, to make this Convention a success in the entertainment line as also has Mr. Horgan, chairman of the Reception Committee. [Applause.]

THE CHAIRMAN:—The joint session will now stand adjourned, but we are all glad, gentlemen, to have you stay here for the session of the American Foundrymen's Association.

THE CHAIRMAN:—The meeting of the American Foundrymen's Association will please come to order. It is with pleasure that I welcome you to this, the seventeenth annual meeting of the American Foundrymen's Association. I do not wish to infringe on your valuable time, but there are one or two things to which I wish to call your attention at this meeting.

First: Our constitution should be so amended or changed that your officers in the future would not encounter the trouble experienced this year in arranging the time for the meeting of this Convention, which trouble was caused by circumstances beyond their control.

Second: Some ways and means should be devised for the advancement of the good work which has been done in the past by the Association and as we are all aware this cannot be done without the support of the industry. Our membership is about seven hundred and I have no doubt could be increased threefold by concentrated effort on our part.

I would therefore respectfully suggest that a committee be appointed at this session to formulate the necessary changes in the by-laws and make report to this Convention at the earliest possible date.

MR. W. H. MCFADDEN:—I move that a committee of seven be appointed by the president for the purpose of carrying out his recommendations in regard to the necessary change in our constitution. Also that the matter of ways and means be referred to the Executive Board.

Motion seconded and carried. Then followed the report of the secretary-treasurer.

REPORT OF THE SECRETARY-TREASURER

We are just recovering form one of the worst periods of depression the foundry industry has passed through in many a year, and hence it is little to be wondered at that our Association has suffered correspondingly. Fully fifteen per cent of the members here either resigned or had to be taken from the rolls this year, and it may be of interest to state that a canvass of the industry just concluded has revealed a surprising number of changes brought about by financial stress.

A vigorous campaign for new members has, however, served to recover some of the lost ground, so that to-day we have 626 members, with more coming in by every mail—showing better than in any other way the resumption of business activity and business optimism. One point, however, needs mention. By far the greater loss in our membership was due to the withdrawal of the supply houses. Various reasons were given for this, when given at all. The principal one was that the exhibition was giving them all the publicity they could hope for and membership was not needed. Now in an association like ours, composed as it is of men who are striving to advance their industry no matter what sacrifices in capital and energy it may bring upon them as individuals, the presence of the sellers of supplies is as a rule an unwelcome one, and indeed many associations expressly keep them out of membership. With us, however, there is recognized that the man who sells us the supplies we need is apt to know very much more about them than we do, and hence we want him with us to talk things over, see where improvements can be made, and to arrive at an understanding which will eliminate unnecessary loss of treasure and time by studying our conditions better. The time is rapidly coming when we as an association will go about standardizing our supplies, and indeed to-day there is a call for a number of such standards. The first will come before you at this convention—namely, the preparation of standard specifications for core binders. We now know sufficient on this subject to enable us to lay down definite requirements for this class of materials, and a committee to do so is recommended for appointment at this meeting. Now unless the manufacturers of core binders are members of the Association, to which membership they are heartily welcome and to part membership of the com-

mittee they are entitled, they will have nothing to complain about if the eventual specifications are in their judgment drawn too tight. They will have neglected their chance to be considered.

It finally boils down to the plain statement that unless the men who sell us goods show their honest desire to advance with the times by holding membership in the foremost association of their customers and working with them for improvement, it will pay these customers to scrutinize carefully every solicitor for business and cut those out who have shown themselves either passive or opposed to advancement. It will not pay to do business with them.

The office of the secretary has been extremely busy these last sixteen months, as will be seen from the magnificent volume we were able to issue for last year's proceedings. The investigations on the molding sands have also progressed, and a large series of tests were published. A preliminary report is given at this meeting. The subject is so fascinating that much more work will be done, new points being brought out all the time during the course of the experiments. It is hoped that the results will indicate to the sand supply man just how he can treat his product to make it more valuable to the foundryman, and incidentally to himself.

Perhaps one prominent thing that has been brought out by this year's correspondence is the almost total absence of systematical records by individual foundrymen on what they have received for their castings. There seem to be few foundrymen who have tried to classify the castings they have sold, and to average for the year just what these classes of castings have brought them.

With our much-vaunted American efficiency of system, this is a very weak point, and we are far behind European countries in so systematizing the office cost, beginning where manufacture leaves off, that we may know just what work we can do best and then go after it. Our Association does not touch the price question in its deliberations, hence this point is given to the individual members for their personal consideration.

The change in date for our convention, necessitated by the extreme winter conditions all over the country and consequent delay in the Buffalo preparations, played rather sad havoc with

the program of papers—our good contributors not caring to write papers during the summer season. The result was the receipt of some twenty papers during the week before the convention, with consequent incipient mental paralysis from the secretary to the printers. If, therefore, the quality of the output to be discussed at these conventions may seem to some not up to their expectations, the following should be remembered: the papers are voluntary contributions of busy men in what is becoming a very restricted field for good papers. While we urge promptness in getting contributions to the press, we are beholden to the courtesy of our contributors, and must follow their wishes rather than the other way round. The foundry education required to-day is not taught in schools, but by hard life experience, hence every year sees at these conventions men who have just become acquainted with our friends silicon and sulphur. Papers must not be written above the quick comprehension of these foundrymen whom it is our work to help along to efficient production for the good of the industry and of the country. If, therefore, papers repeat what is known to most of us, allowance should be made, and if every paper contains simply one point that makes some of us think, the convention has been a success.

A remarkable interest is being taken by the Malleable Casting and Steel Casting men in our Association at the present time. It argues well for the industries in question, as a frank discussion of methods of manufacture eliminates waste, as well as educates the consumer up to what can be done in the foundry and what should not be expected of it. We sincerely hope that these two branches of the iron industry will combine to make our conventions the medium of their technical deliberations right along, and thus increase our publications in value to the membership at large. The steel castings session of last year has attracted widespread attention, foundrymen in the business as well as facing being forced into it, found the discussion of utmost value in clearing up disputed points. The present program promises further food for thought in this direction.

One very pertinent thing should be mentioned here. In the malleable casting trade—as is known by personal observation of your secretary—there is exactly the same room for a full session's work at this convention. The lack of knowledge in view of what has been published is actually lamentable at times, and the

malleable men owe it to themselves to get out of their shell, as the steel casting men have done, and get busy in the public light. The consumer has a right to it.

The government has almost concluded the investigations on the cupola melting problem, at the Pittsburgh plant of the United States Bureau of Mines. You will have a preliminary report at one of the sessions, through the courtesy of Dr. Holmes, the director, and our warm friend.

Industrial education is coming to the front more and more in this country, and your able chairman of the Committee on Industrial Education is making a name for this Association in educational circles. It is becoming clearer every day that if we are to hold our own—not to speak of progressing—in the rush of the nations toward a future that seems as unknown as it is terrifying, we must have compulsory attendance in continuation schools in our educational system. We should give thought, very earnest thought, to the subject, not as manufacturers, nor as working men—for we are all working men—nor as educators only, but as plain citizens who see a menace before us affecting the future of the country. There are not men enough to do the world's work at the present time, apart from all questions of compensation.

The financial situation of the Association is distinctly good. It is the aim of your Board of Officers to give as much literature to the membership and to economize on the other expenses incident to conducting the Association, as possible.

RECEIPTS FOR THE FISCAL YEAR JULY, 1911, TO JULY, 1912.

Balance	$366.85	
Dues, sales, etc	4,795.24	
Total		$5,162.09

DISBURSEMENTS FOR SAME PERIOD.

Transactions	$2,775.48	
Printing	84.05	
Salaries	1,200.00	
Convention expenses	255.38	
Sundries	67.62	
Postage	411.00	
Total		4,793.53
Leaving a balance in the treasury, July 1, 1912, of		$368.56

The molding sand tests have exhausted the special fund collected several years ago, and the work will go on the account of the Association hereafter as it can be handled.

The relations with our sister societies across the ocean have been most pleasant, and particular mention should be made of the development of the Foundrymen's Association of France. The office of the secretary of our Association has been heavily drawn upon during the year for technical information, showing how the shoe has pinched in many establishments owing to the deplorable financial and manufacturing situation just passed. We are always glad to assist in every way possible and urge our members not to hesitate to write when they are in doubt.

The secretary finally has to thank the board and membership at large for the uniform courtesy extended him in his work, and hopes that the same interest continue which has in the past been so potent in building up the standing of the Association in the regard of the industrial world.

Respectfully submitted,

RICHARD MOLDENKE,

Secretary-Treasurer.

THE CHAIRMAN:—We will now have the report of the Auditing Committee.

MR. GALE:—Mr. President, the Committee appointed at the last meeting to audit the books and accounts of the secretary-treasurer, beg leave to report having done so and that we find the accounts kept in a very methodical manner and correct in all respects.

THE CHAIRMAN:—Next comes the report on "Cast Iron at the International Testing Congress of New York"; by the Secretary.

THE SECRETARY:—Mr. President, two weeks ago there was a very important congress held in New York City, the Congress of the International Society for Testing Materials, some of the members of which you have had in Buffalo last week. There was one session of the cast iron section and I thought it might perhaps be of interest to our Association to give a résumé of what happened there.

Dr. Moldenke then read his report, which is to be found on page 373 of this volume.

The Chairman:—Gentlemen, I appoint on the Committee for the Revision of the By-Laws, Mr. R. A. Bull, Mr. W. A. Bole, Mr. Alfred E. Howell, Mr. J. S. Seaman, Mr. H. D. Miles, Mr. F. B. Farnsworth and Mr. T. W. Sheriff. I appoint the Auditing Committee the same as last year, Mr. Yagle and Mr. Gale. According to a change that was made in our custom last year, the committee for the nomination of officers for the ensuing year is to be composed of the past presidents of the Association. There being only two present at the moment, I will appoint the committee a little later. I would, however, like the Committee on the Revision of the By-Laws to meet as soon as possible and give us their report, so that we can have ample time to take the matter up and make the necessary changes.

The next report is the report of the Committe on Standard Methods of Coke Analysis, by Mr. H. E. Diller. These methods were printed and put before the Association last year and they have been left to be commented on by the chemists and metallurgists of the country. We have received no criticism of these methods and no objections, so it seems that the chemists of the foundries are probably satisfied with the report as published last year. This report is published again this year in the expectation of having our Association adopt these methods as their standard.

Mr. Lane:—I move that this committee report be accepted as the standard of the Association. The motion was seconded and carried. The report is to be found on page 143 of this volume.

The Chairman:—Mr. Kreuzpointer, will you be kind enough to report for the Committee on Industrial Education?

Mr. Kreuzpointer:—Mr President and Gentlemen: In one of the normal schools of Pennsylvania, the principal continually and habitually used a saying which he impressed on his students—"That those who cease to go up begin to go down." I am mindful of the fact that this same saying is just as applicable to our industry and all of our business. In other words, if we don't keep going up, we begin to go down, and your Committee on Industrial Education was guided by this fact in trying to present to you this morning their report on industrial education in such a manner and presenting such suggestions as may be helpful, not only to the foundry industry, but also to all industries, to help us to go up and prevent us going down.

The subject of industrial education is such a complicated one that your committee to-day repeatedly and earnestly requests the co-operation of all industries and all business people with our schools. We are working under very great disadvantages in comparison with our European friends in their schools, and one of the greatest needs now is that committees be formed through chambers of commerce, or in one way or another, to co-operate with our schools and inquire into their needs.

The chairman of your committee has found, in a number of cities, superintendents of the school system who have told him that they were ever so willing to do all they could, but politics prevented them from doing their best for the industry and the business interests of the city. Here, then, the business man and the industrial man have to step in. Let me call your attention, for instance, to three cities I have in mind where politics still has a good deal to do in the administration of the school authorities. Here they cut down the appropriations for the schools and consequently reduce their efficiency. Again, I have a city in mind where, according to the law, the school principals are paid according to the number of scholars in their school. That is to say, if a principal has 900 pupils in his school, he is paid, say, $1,500 or $1,800 a year, and if he has 1,200 or 1,500 pupils in his school, he is paid more. Now, I have been present when two boys who wanted to get into a continuation school could not get a decision from the principal, because he was actuated by the fear that the continuation school and the industrial school would draw so many pupils away from him that his pay would be cut.

Now then, it is up to you gentlemen of the industry, it is up to business people, to inquire into such conditions and help the school authorities to rectify them; otherwise, all the work of the schools will be minimized to a large degree. For instance, in that city of which I just spoke, I know that the industrial teachers and those in the technical high school do the best they can, but they are hampered by this drawback hanging on them, that the boys are prevented from getting into the continuation schools. The continuation schools are not trades schools, they are preparatory schools for all kinds of industrial schools, and they deserve our most sincere support in every respect.

Let me make only one more point. If we, in this country of

wealth and great resources, are stingy in supporting these industrial schools, we cannot keep up our struggle for supremacy and the high standard of living we have attained, due to our energy and intelligence. In the city of Munich they pay $27.50 per pupil in the elementary schools and $21.25 for every boy from fourteen to eighteen in the industrial schools. In the city of Leipsic they pay 5 cents per capita for industrial education alone. The Kingdom of Prussia pays $50,000,000 a year for industrial education and industrial schools, and the municipalities besides pay for all the equipment and teaching. In view of such sacrifices by the people over there, and in France, Switzerland and Austria, who are competing with us in the markets of the world, we will not be able to keep up our standard. If we do not give a good industrial education to the 20,000,000 or 24,000,000 of skilled, semi-skilled and unskilled workmen of this country, we will fall behind in the race. [Applause.]

(Adjourned until 2 P. M.)

SECOND SESSION. TUESDAY, SEPTEMBER 24TH, 2 P.M.

President Speer called the meeting to order and announced the various papers in turn.

Malleable Cast Iron and the Open Hearth Furnace, by G. A. Blume, of Stockholm, Sweden. In the absence of the author, the secretary gave a brief description of the points brought out by this interesting discussion of a live topic in malleable circles. The paper is printed and can be found on page 431 of this volume.

Memorandum on Titanium in Malleable Castings Practice, by C. H. Gale, of Pittsburgh, Pa. Mr. Gale read his paper, which is printed on page 353, and the discussion which followed is given on page 459.

The Great Economies produced by Continuous Foundry Installations, by George K. Hooper, of New York City, was next presented by the secretary, who reviewed the points brought out and commented upon them (page 175).

The Foundry and the Pig Iron Market, by A. I. Findley, editor of the *Iron Age*, was next taken up, and the timely and able

paper read by the colleague of Mr. Findley, Mr. W. W. Macon (page 339).

Mechanical Sand Tempering, by V. E. Minnich, New York City, was next taken up, Mr. Minnich explaining his method of tempering sand in the foundry by mechanical means instead of by hand (page 231). In the discussion that followed the following developed:

THE SECRETARY:—I was over at the exhibition last night and saw the machine Mr. Minnich is exhibiting there, and one of the European visitors wanted to know why he didn't add taking the shot out of the sand while he is cutting it.

MR. MINNICH:—I have considered that and it is a rather difficult problem in the right sense of the word. If the blades were used in taking the shot and other magnetic matter out of the sand, it would soon clog them so that they would not work at all. It might be hard to prevent their becoming clogged and magnetizing the whole machine and giving the operator a shock. I am working on a plan for accomplishing this and have not yet abandoned hope. But it does not look very promising at present.

THE CHAIRMAN:—We will now have Mr. Dudley's paper on *Some Thoughts on the Problem of the Foundry.*

The secretary presented Mr. Dudley's paper and explained the thought developed in it (see page 241). On page 461 will be found the discussion that followed the presentation of this paper.

Compressed Air—A Foundry Necessity, by Arthur P. Murray, of East Cambridge, Mass., was presented by the author and copiously illustrated with lantern slides (see page 243).

The Heating and Ventilating of the Foundry, by W. H. Carrier, of Buffalo, N. Y., was then presented by the author, and also well illustrated by lantern slides (see page 297).

Both papers were well received and given close attention. The session then adjourned until Wednesday morning.

On Tuesday evening a magnificent banquet was tendered the Associated Foundry Foremen. The guests of Buffalo and its local committee enjoyed themselves splendidly and a fine social time was had. A number of speakers discoursed wit and philosophy, and a vaudeville entertainment concluded the enjoyable evening.

THIRD SESSION, WEDNESDAY, SEPTEMBER 25TH, 10 A.M.

President Speer called the Convention to order September 25th, at 10 A.M.

MR. BULL:—I would like to make a partial report for the Committee on Revision of the Constitution. This committee—that is, all the gentlemen who are in town, which includes all that were appointed by the President yesterday, with the exception of Mr. Farnsworth and Mr. Sheriff—met yesterday to discuss the matter and this partial report has reference to Section 1 of Article IV of the Constitution, which reads as follows:

"There shall be an annual meeting of this Association during the month of May, the date and location of which shall be fixed by the Association at its regular annual meeting, provided that if no time and place are determined upon at the annual meeting, the Executive Board shall fix the time and place at least three months in advance of the said meeting. Twenty-five members shall constitute a quorum of the Association." We propose a revision of this article, striking out certain words and making it read thus:

"There shall be an annual meeting of this Association, the date and location of which shall be fixed by the Executive Committee at least three months in advance of the said meeting."

The Committee at this time wishes to make a partial report so far as this article is concerned, and will recommend certain other changes which have not been fully agreed upon as yet.

The report of the committee was received and filed for action when the balance of the report would be presented. The president then called for the first paper of the morning.

Electric Welding, by J. F. Lincoln, Cleveland, Ohio. Mr. Lincoln presented his paper, which will be found on page 329. The discussion which followed is reported on page 457.

The Economic Side of the Twelve-Hour Shift in the Steel Foundry, by R. A. Bull, of Granite City, Ill., is given on page 131, and the discussion on page 455. Mr. Bull presented his paper before a notable assemblage of representatives of the steel casting industry, and it drew out considerable discussion at the time, and subsequently among foundrymen and the daily press.

President Speer then gave the floor to Mr. Tracy, who made the following announcement:

Mr. Tracy:—President Speer and Gentlemen: We have a new program, which is just from the press, and which is changed in one particular, and I want to put a copy of it into the hands of every gentleman present. For the boat ride around Grand Island, the boat will start promptly at 2 P.M. to-day from the foot of Main Street. This is one of the prettiest trips of its kind in the country, if not in the world. A stop will be made at the works of the Wickwire Steel Company, and Mr. Wickwire, who is a member of the Entertainment Committee, has arranged to tap a cast from the blast furnace at the time the delegates of this Convention arrive at the plant, so you will have an opportunity to see the whole process as it takes place. I want to call your attention at this time to the subscription dinner which will be held in this room, to-morrow, Thursday evening, at 6:45. As chairman of the Convention Committee, I think I may be permitted to say a word in regard to this dinner. I am not a foundryman, but the work of the Chamber of Commerce is being carried on through the civic interest and liberal spirit displayed by the Local Committee. Their money is paying for your entertainment and I can say to you that I think that while the nominal price of $3.00 per plate is charged for this dinner, that amount will not half cover the cost to the Local Committee, but, owing to a fixed rule made by the American Foundrymen's Association, they found it necessary to make a charge and therefore the price was fixed at $3.00, but they could just as well have given you the dinner without any charge if it were not for this rule. Now, we will have to start with, a very elaborate menu, and we will have Secretary of Commerce and Labor Nagle of Washington, who will address us and who has been secured after a great many days of hard work, and we will also have Elbert Hubbard of the Roycrofters' shop at East Aurora. These are both very good speakers, and Mr. Nagle will give you information which you will want to receive, and Mr. Hubbard is a very witty speaker. This, with the entertainment provided, should make a feature which none of you can afford to miss.

The Chairman:—The next paper before you is that of Mr. Samuel R. Robinson, of Coraopolis, Pa., entitled *Some Salient Points of the Modern Steel Foundry.* Mr. Robinson presented his paper, which may be found on page 213, and the discussion on page 453.

Open Hearth Design and Manipulation as Applied to the Steel Foundry, by John Ploehn, of Davenport, Ia., provided an interesting paper as presented by the author, as it touched particularly on points of operation which are not usually presented to the public. There have been calls for this paper from all over the world, and an extra supply has been arranged for so that our members may be accommodated if they want additional copies. The paper is to be found on page 357, and the discussion on page 465.

President Speer then appointed the Nominating Committee, consisting of the past presidents attending the meeting, namely, Messrs. Seaman, Anthes and McFadden; and Messrs. Howell and Bull, vice-presidents of the Association, in addition, to make five members. He then called upon Mr. R. A. Bull to preside.

Economical Cleaning of Castings, by B. H. Reddy, of Cleveland, Ohio. This paper was duly read by the author, and proved very interesting.

The session was then adjourned until Thursday, at 10 A.M.

During the afternoon a most enjoyable boat ride around Buffalo Harbor and along the river until close above the Niagara Falls—the spray of which could be observed right ahead—was enjoyed by the entire convention. Two sound and comfortable steamers carried the foundrymen and their ladies over the waters, once just getting a little of the swells of the Lake. The fine shore line teeming with industry was admired, and on the return a stop was made to see a furnace cast at the Wickwire Furnaces.

In the evening a dinner was given the officers of the Allied Associations by the Chamber of Commerce, at which His Honor the Mayor was present.

FOURTH SESSION, THURSDAY, SEPTEMBER 26TH, 10 A.M.

President Speer called the meeting to order at 10 A.M.

THE CHAIRMAN:—At the session yesterday morning, the papers in the steel section were not quite completed and I do not know what happened to the majority of the steel people this morning; I see very few here, so I thought we could leave the steel

paper until we gathered a little better attendance, and we will take up a couple of the papers that were on the program for this morning. The gentlemen who wrote the papers are not here, but their papers are here and the Doctor will be kind enough to give a synopsis of the two papers, and by the time we get through with them we can take up the steel section and finish the work. We are limited for time to-day and have a great deal to do, especially at our afternoon session. The election of officers and other new business which comes before you ought to be attended to and we ought to have time enough to understand the questions to be presented. The first paper is *The Lighting of Fires in Cupolas*, by Mr. A. H. Stein, of Brooklyn, N. Y. This was read in abstract by the secretary, and will be found on page 225.

THE CHAIRMAN:—The next paper we will take up is *Mystery versus Chemistry in Grading Pig Iron*, by Mr. Thomas D. West, of Cleveland, Ohio. Mr. West read his paper, which will be found on page 127.

THE CHAIRMAN:—To complete the work of yesterday's steel casting session, we will now take up the paper of Prof. Bradley Stoughton, on *The Cleansing Effect of Titanium on Cast Iron*.

This paper, presented by the author, was thoroughly discussed and the subject gone into deeply, showing the interest taken in the matter of purifying our castings from oxidation and mechanical admixtures before pouring. The paper is given on page 309, and the discussion on page 324 a.

The Premium System as Applied to the Finishing Department of a Steel Foundry, by A. W. Gregg, of South Milwaukee, Wis., was then read by the author. It is given on page 347. This closed the steel casting section work. While getting ready to take up the iron foundry papers for the session, the following transpired:

THE CHAIRMAN:—There has just arrived among us a distinguished metallurgist from the other side, Prof. Emil Heyn of the Royal Prussian Testing Laboratories near Berlin, Germany. I would like to introduce him to you. [Applause.]

PROF. HEYN:—Mr. Chairman and Gentlemen: I am very much surprised and at the same time very gratified at your kindness in welcoming me here to-day. I have read very much about

your meetings and the work you are doing, and I have availed myself of the opportunity which was given me by the Congress of the International Association for Testing Materials in New York, to see personally and to be personally for a little while in the midst of your pleasantly and happily conducted meeting. I think from what I saw at the exhibition and from what I have heard here, that this will be a very profitable convention and I shall carry away with me a very good impression of the very ingenious work which is done in this country in the foundry business. [Applause.]

THE CHAIRMAN:—I see a decoration on our good friend's coat, but I notice that he has missed that of our Allied Associations—and I wish to present this to you, sir, which is the official badge of the American Foundrymen's Association, and wish you would wear it. (Major Speer pins his own badge on Prof. Heyn's coat.) [Applause.]

PROF. HEYN:—Thank you very kindly.

THE SECRETARY:—Prof. Heyn is very modest. He is one of the famous men of Germany, sent over here by the Emperor of Germany and his government to attend the Congress of the International Society for Testing Materials. He has passed around the country in company with Privy-Councillor Martens, who is unfortunately too ill to attend our Convention this morning. I met Prof. Heyn on the other side in a large gathering of foundrymen and we discussed foundry questions so vigorously and late one night that they had to take me to a Rathskeller and strengthen me with a great big stein of their famous "Münchner." [Applause and laughter.]

Mr. P. Munnoch then read his paper entitled *Air Required for Combustion in the Cupola, and a simple Blast Velocity Gauge.* This paper, printed on page 161, was discussed together with other papers on cupola practice.

THE CHAIRMAN:—Before introducing the next paper, Mr. Thompson, who is the president of the Allied Foundry Foremen's Association, has asked the privilege of the floor for just a moment.

MR. THOMPSON:—Mr. President and Gentlemen: We have, in the Foundry Foremen's Association, at times foremen out of positions, and they write the secretary of that Association to try and get them a position. Now, this morning we have elected a new set of officers and I am secretary. We want to try and get

our members positions, along with other things that we intend to do for them, and I would like the American Foundrymen in need of a foreman to write the secretary of the Foremen's Association, and we will try and put him in touch with a man who perhaps will fill the bill for him. The Foremen's Association has adjourned to meet with the next meeting of the American Foundrymen's Association.

The Chairman then called upon Dr. Moldenke for his paper on *Rational Cupola Melting Practice.* Dr Moldenke gave an abstract of this paper, which was discussed with the others on cupola practice. The paper is given on page 421.

THE CHAIRMAN:—I have the pleasure of introducing to you one of our government experts, who has been doing a great work in metallurgy for the foundry interests: Mr. A. W. Belden, of the United States Bureau of Mines, who will give an illustrated paper on the Government Cupola Tests. [Applause.]

Mr. Belden then presented his paper, the discussion of which is given on page 469.

NOTE BY THE SECRETARY:—As Mr. Belden's paper is an advance presentation of the results of a very elaborate series of tests and investigations conducted under the auspices of the United States Bureau of Mines, and these results have not yet been issued by the government, under the law, they cannot be given out until first printed by the government. Arrangements are being made to get the text, or if possible the necessary additional copies of the respective bulletin, for inclusion in our volume, so that our members may have the information in full in print for their study.

The chairman then gave the floor to Prof. Johnson, of the Wentworth Institute of Boston.

MR. JOHNSON:—I wish to state, in view of the fact that my paper has been put over until the afternoon, that I thought it well to say just a word relative to what it will contain, in view of the fact that the Wentworth Institute has just acquired an endowment of $3,500,000 and is to be a large factor in the field of industrial education. I am sure that most of you will be interested in what I will have to show you. I have some views covering this line of work that I am satisfied will allay some of the ideas that are prevalent relative to what the work of industrial education really is.

FIFTH SESSION, THURSDAY, SEPTEMBER 26TH, 2 P.M.

President Speer called the meeting to order at 2 P.M. The first paper was by Mr. James Glass, of Pittsfield, Mass, *On Patternmaking.* Read by the secretary in abstract, and printed on page 219.

Recovery of Shot in Small Foundries, by S. A. Capron, of Westfield, Mass. This paper was also read in abstract by the secretary. Printed on page 197.

About Sheradizing, by Thomas Liggett, Jr., of New Castle, Pa. Printed on page 187. This paper was reviewed by the secretary, who explained its points.

Some Short Cuts in the Foundry Laboratory, by P. A. Boeck, Worcester, Mass. The contents of this paper were discussed and presented by the secretary. Published on page 379.

The Importance of Despatching in the Foundry, by C. E. Knoeppel, of Buffalo, N. Y., was also presented by the secretary. Page 201 of this volume.

The reading of papers was then interrupted to receive the report of the Nominating Committee, which reported through its chairman, Mr. Joseph S. Seaman.

MR. SEAMAN:—Mr President and Gentlemen: The Nominating Committee beg to report the following list of officers for the coming year as their recommendation:

For President:	H. D. Miles, Buffalo, N. Y.
For Vice-Presidents:	F. B. Farnsworth, New Haven, Conn.
	T. L. Richmond, Buffalo, N. Y.
	Walter Wood, Philadelphia, Pa.
	Alfred E. Howell, Nashville, Tenn.
	R. A. Bull, Granite City, Ill.
	T. W. Sheriff, Milwaukee, Wis.
	G. R. Lombard, Augusta, Ga.
	S. B. Chadsey, Toronto, Ont.
For Secretary-Treasurer:	Richard Moldenke, Watchung, N. J.

On motion of Mr. Howell, the report of the Nominating Committee was adopted by a rising vote, the vote being unanimous. On motion of Mr. McFadden, the ballot of the Association was cast by the secretary for the nominees recommended by the

Nominating Committee. The chairman appointed Mr. Seaman to escort to the platform the newly-elected president, Mr. Miles.

President Speer:—Mr. Miles, in handing over to you this gavel, it is my sincere wish that you will meet with the same friendship and the co-operation of the members of our Association as I have in the past two years. In handing over this gavel to you, I wish to emphasize the fact that it is the first gavel that was used by any Foundrymen's organization, and dates back to twenty-five years ago. It was presented to me by our friend Mr. Pero, of St. Louis, and it affords me great pleasure to place it in the archives of our Association for use by all our coming presidents. Take it, sir. I wish you success. [Applause.]

President Miles:—Members of the American Foundrymen's Association: I want to thank you very much for the honor conferred, which I deeply appreciate. I also appreciate very much being escorted to the platform by the Nestor of America's Foundrymen, Mr. Seaman. I have been a member of this Association some years, and have more recently taken quite a little interest in it. I am sorry that my duties here as local chairman have prevented my attending the meetings to some extent and that I have been able to be here so little, but the work was so varied and there were so many things going on, that I had to be out of the building a great deal. The American Foundrymen's Association, being an educational institution, is doing a splendid work, and I was very glad to hear Prof. Heyn, this morning, give it praise by saying that it was the leading organization of its kind in the world. The work done by your worthy president, Major Speer, and our very efficient secretary, Dr. Moldenke, has advanced the Association greatly, and the work is improving every year. Dr. Moldenke has been in the Association, I understand, since its inception, or nearly so, and has accomplished a work that is second to none in the educational line in the foundry business. He is equipped with the scientific education necessary to carry on the work to the best advantage. I trust that each member of the Association will, in the coming year, endeavor to secure one more member in his locality, so that we may double the membership, if possible; so that, by increased membership and the larger revenues accruing therefrom, we may be able to carry on the work to still better advantage, as funds are needed for doing the work

properly. I am sure that the vice-presidents and the former presidents, of whom I am glad to see so many here and taking so much interest in the Association, will do their share toward increasing our membership and stirring up the interest of members in their respective districts. [Applause.]

MR. SEAMAN:—Gentlemen, some of you know the close relationship that has existed between Major Speer and myself for a number of years. Possibly some of you are aware that at the close of every convention we have held in the past it has been my privilege to offer a resolution in regard to the retiring president. That will now be my pleasant task to perform to-day, and I must say that I have never performed the duty with more pleasure than at this time. I desire to offer the following resolution:

Resolved, That the American Foundrymen's Association in Convention assembled hereby extends its sincerest thanks to Joseph T. Speer, who for the past two years has so ably served it as president and during his term of office has devoted unsparingly his time and attention to the upbuilding of the Association and diplomatically conducted its business; strengthened its position, outlined its policies and established it on the basis of friendly relations with all affiliated bodies.

As an appreciation of the whole-souled work he has done in behalf of this Association, both as its President and as an active member in the past, be it hereby

Resolved, That Joseph T. Speer be and he is hereby unanimously elected as an honorary member of this Association with a full vote and voice in its deliberations during the remainder of his life.

PRESIDENT-ELECT MILES:—It will give me special pleasure to put this resolution.

The resolution, after being seconded by Mr. Howell, was put and unanimously carried.

President Speer rose to reply, but was so choked with emotion that he could only say a few words of thanks, and had to resume his seat. [Great and continuous applause.]

The following motion was then adopted unanimously:

Resolved, That the American Foundrymen's Association, in Convention assembled, takes this opportunity to extend to Dr. Richard Moldenke, its secretary-treasurer, its hearty appreciation

of his services during the past year, and for many years past, in furthering the interests of the Association, in the development and research work which he has given so unsparingly. And be it further

Resolved, That this vote of thanks be spread upon the minutes of the Association as a permanent testimonial of the appreciation of the Association for these services.

The Secretary:—Gentlemen, I cannot express myself sufficiently for the kindness that you are doing me, and I know that I may say the same for Major Speer, because we have worked together so much during the last few years and we have struggled, and fought, and tried to do the best we could for our country and our industry, in this work of ours. I am sure he thanks you very warmly and heartily and I know I do, and we will try to keep on with our work as long as life lasts.

The following resolutions was then unanimously adopted:

Resolved, That the American Foundrymen's Association and its allied affiliations take this opportunity to publicly thank the citizens of Buffalo, the Mayor and the City Officials, the Buffalo Convention Committee, the Chamber of Commerce and the hotels of the city for the uniform courtesy extended to this organization as such and to its members as individuals during this Convention; to express our gratification upon having come to a city as hospitable as Buffalo and to congratulate the city and all who took part in the eleborate arrangements necessary to so ably meet the demands made upon it by a Convention such as ours.

We also wish to commend the local committees for the thoroughness with which they took care of details and provided facilities which have made this Convention one of the most successful in the history of the Association.

This organization also wishes to extend its congratulations and sincere thanks to the members of the local entertainment committee for the able manner in which they conducted their affairs and to thus publicly express our appreciation of their splendid efforts.

President Miles:—Gentlemen, as a citizen of Buffalo and a member of the Chamber of Commerce and chairman of the local committee, I want to thank the Association for those words of appreciation. I am sure that all the citizens of Buffalo who

have had anything to do with the Convention will appreciate them very much, as so many of us have worked hard to make this meeting successful and have seen that our efforts were appreciated.

THE SECRETARY:—I would like to offer a resolution that we give our special thanks to the gentlemen who have written our many and able papers. It is so very hard to get papers that when we do get them we want to thank them very heartily.

MAJOR SPEER:—I second that motion. Motion carried unanimously.

THE CHAIRMAN:—Mr. Bull, we will be glad to receive your report on amendments to the Constitution and By-Laws.

MR. BULL:—The Committee hereby report that in their opinion it is advisable to make the following amendments. The Constitution, Article II, Section II, now reads as follows:

"Any person, firm or corporation engaged in the production of castings of any kind, as employer, superintendent, foreman or chemist, may be elected an active member; and any associate member may become an active member when recommended by the Executive Board and approved by a majority vote of the Association at any regular meeting."

We recommend that this be changed to read as follows:

"Any person, firm or corporation engaged in the manufacture of castings of any kind, as employer, superintendent, foreman or chemist, may be elected an active member; and any associate member may become an active member by a majority vote of the members of the Executive Board."

Article II, Section III, reads as follows:

"Any person whose knowledge or services are valuable toward the objects of this Association, may be elected an associate member."

We recommend that this be changed to read as follows:

"Any person whose knowledge or services are valuable toward the objects of this Association, may be elected an associate member. Associate members shall have all the rights of active members, except the power to vote."

Article III, Section I, of the Constitution, reads as follows:

"The officers of this Association shall consist of a President, eight Vice-Presidents, a Secretary and a Treasurer, who shall, together, form the Executive Board of this Association."

We recommend that this article be changed to read as follows:

"The officers of this Association shall consist of a President, eight Vice-Presidents and a Secretary and Treasurer, who shall, with the past Presidents of this Association, form its Executive Board."

Article III, Section II, of the Constitution, reads as follows:

"The eight Vice-Presidents shall be elected from their respective districts as follows:

"(1) New England States.

"(2) New York and New Jersey.

"(3) Pennsylvania, Delaware and Maryland and District of Columbia.

"(4) Michigan, Ohio, Kentucky and Tennessee.

"(5) Indiana, Illinois, Missouri, Kansas, Colorado, New Mexico, Utah, Arizona, Nevada and California.

"(6) Wisconsin, Minnesota, Iowa, North Dakota, South Dakota, Idaho, Nebraska, Montana, Wyoming, Washington and Oregon.

"(7) Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma and Texas.

"(8) Provinces of Ontario and of Quebec, in the Dominion of Canada.

It is recommended that the above be omitted entirely, as it has been quite difficult to strictly follow the Constitution in that respect. Article IV, Section I, reads as follows:

"There shall be an annual meeting of this Association during the month of May, the date and location of which shall be fixed by the Association at its regular annual meeting; provided, that if no time and place are determined upon at the annual meeting, the Executive Board shall fix the time and place at least three months in advance of the said meeting. Twenty-five members shall constitute a quorum of the Association."

We made a partial report yesterday morning, which bears on that section, but, for the information of those who were not here, I will repeat the proposed amendment, which reads as follows:

"There shall be an annual meeting of this Association, the date and location of which shall be fixed by the Executive Board

at least three months in advance of the said meeting. Twenty-five members shall constitute a quorum of the Association."

Section XIII of the By-laws, under the head of Amendments, reads as follows:

"These By-Laws may be amended at any regular meeting of the Association by a two-thirds vote of those present, provided the affirmative vote represents a majority of the members of the Association, and provided, also, that in case the required majority be not present, the Secretary shall, within thirty days after adjournment, submit the proposed amendment for letter ballot by mail."

We recommend that this section be changed to read as follows:

"These By-Laws may be amended at any regular meeting of the Association by a two-thirds vote of the members present, provided the Secretary, through letter ballot, submit it to all active members, within thirty days after adjournment, and provided it shall secure, within thirty days after the submission of said letter ballot to the members, a ratification of the amendment by a majority of the letter ballot, signed by those voting."

The adoption of the report was moved and seconded.

THE CHAIRMAN:—I might say here that these amendments were made as seemed necessary in order to make the carrying on of the work of the Association more easily accomplished and the rules more flexible. This committee was appointed and considered the various amendments made very carefully; also, that Major Speer and Dr. Moldenke and some of us here thought these were good changes to make, but, as there are quite a number of them, we will be glad to answer any questions or hear any objections.

MAJOR SPEER:—I would like to say a word in connection with the changing of the time and place of meeting. Your Executive Committee and your officers had to violate our Constitution last year in changing the meeting date from May until this time. You may not be aware of the fact that after, in open Convention last year in Pittsburgh, this Association decided to meet this year in May, in Buffalo, we found in the meantime that the building in which one of the affiliated organizations had contemplated holding its meeting, had been condemned, and the building could not

be obtained. The local Committee, after a great deal of trouble, took the matter up and had the City Council appropriate and spend over $160,000 in putting the building into proper condition. Their contractors were penalized to have the building in shape for May. As you are all aware, in the hard winter we just passed through, they couldn't do any erecting; the contractor fell down on account of labor troubles and other things, and it was impossible to hold our meeting at that time. Our Constitution gave no leeway to your officers, and we were forced, under the circumstances, to change the date, and I think it is very essential to give your officers all the support you can and make the Constitution as liberal as possible. I think the committee have done their work well and it is better for the organization.

Mr. Seaman:—Mr. Chairman, as our Constitution requires two-thirds of the members present to vote on this, I move you that a rising vote be taken, so that there be no trouble in regard to that requirement.

The amendments were then unanimously adopted by a rising vote.

The Secretary:—I recommended in my report that the Association authorize the appointment of a committee to take up the question of standardizing core binders. In other words, we want to begin to get at our supplies and get them standardized, and if you will authorize the President to appoint a committee, we will get that attended to during the year and have it ready for you at our next Convention. I would like to make a motion that the President be empowered to appoint a Committee on the Standardization of Core Binders.

The motion was seconded and carried.

The Secretary:—The next order of business would be the letters of invitation we have received for next year. We have several invitations. San Francisco invites us for 1915, for the Exposition, and Boston for 1914. Then, for next year, we have invitations from two cities. From Chicago we have received, through the Chicago Association of Commerce and the Chicago Foundrymen's Club, an urgent invitation that Chicago be selected for next year. And we have received an invitation from the Citizens' Business League of Milwaukee, also a telegram this morning asking us to come to that fine city in 1913. Now, Mr.

Chairman, I move you that this matter be referred to the Executive Board, as provided in our Constitution.

The motion was seconded and adopted.

THE CHAIRMAN:—After the papers that are still to be heard, are read, and the meeting adjourns, I would like to have a meeting of the Executive Committee. I will ask Major Speer to preside again, if he will be so good. (Major Speer takes the Chair.)

THE CHAIRMAN:—The next matter is a paper by Mr. W. H. Cameron, of Chicago, on *Accident Prevention and Safety Devices for the Foundry*. Mr. Cameron read his paper and showed a large number of lantern slides to illustrate his points. The paper is published on page 299.

Next came Prof. Edw. A. Johnson with a paper richly illustrated by lantern slides, showing the work done by the boys in the Wentworth Institute Foundry, where a special course in foundry instruction is given. The paper is given on page 681.

THE CHAIRMAN:—Gentlemen, we have about finished the last work of the Seventeenth Convention of the American Foundrymen's Association. Before adjourning, I would like to thank everybody that I have come in contact with for the support and loyalty given to the Association. If there is no other new business, a motion to adjourn will be in order.

On motion, the Convention then adjourned.

The crowning glory of the Buffalo Convention was the subscription banquet given on Thursday evening. The great banquet hall of the Statler Hotel was completely filled, each of the round tables about which were seated groups of congenial spirits, was decorated with flowers, and the hall itself was prodigally embellished with the product of garden and conservatory. Music was furnished throughout the elaborate dinner, and at the speaker's table itself, laden with flowers and elegantly arranged, were seated the notable speakers for the evening. Not only was Buffalo's poet present, gracing the occasion with recitations emanating from his own genius, and in them rivaling James Whitcomb Riley, but speakers of national reputation held the audience spellbound at times.

It was late when the assemblage adjourned and our American foundrymen scattered in every direction from the hospitable city of Buffalo. Two of the addresses promised so much of value to our members that your secretary had the official stenographer take them down. They follow herewith, and will prove solid as well as entertaining reading for a leisure hour. Since the reporter also got some more material, notably the remarks of the efficient toastmaster, this is given also.

THE BANQUET.

President Miles:—Gentlemen, owing to the very efficient Chairman of the Entertainment Committee, we have, this evening, a banquet that will set off, in a most successful manner, the very successful convention we have had in Buffalo this week. We are told by our guests and the members of the various associations that this is the most successful convention of the allied foundry interests that has taken place. We are glad to hear these praises. We at least feel that we have accomplished much, and I am therefore glad to introduce to-night as toastmaster a man who, though not a foundryman, is associated in a way with the foundry interests, being secretary of at least two companies in the foundry business. I therefore take pleasure in introducing Mr. Slee, of Buffalo. [Applause.]

The Toastmaster: Mr. President, Ladies and Gentlemen: When I was articled to the practice of that engaging profession known as the law, I was instructed that the whole duty of the modern corporation lawyer was to swear off taxes and to plead to indictments. I find in the delegation of the pleasant task of toastmaster to-night, at least in the mind of my genial friend, Mr. Miles, an extension of those accustomed functions. I asked him why he didn't take this place, as his friends desired, and he replied by asking me if I had heard the true story of Daniel. I told him I had not heard the true story of Daniel. "Daniel," said he, "when thrown into the den, met the advancing lions with the shrill proclamation that after they had finished their meal, they would be called upon for a speech." [Laughter.] "They thereupon, suddenly bereft of appetite, shrunk into their corners

and Daniel emerged unscathed." [Laughter and applause.] The application of this tale is various. Either my friend sought to gorge in proper person and to starve vicariously in me, or he thought to test the conduct of a modern Daniel in this assemblage of lions at this table. [Laughter.] It has been suggested, however, since I sat down, that the underlying cause of my appointment might be the interest my friend feels in his new vacuum dryer. [Laughter.] The principle of that dryer, as I understand it, is the extraction of hot air from an absolute void [laughter and applause], and he doubtless intended to view the application of that principle in my efforts here and guide his future conduct by my achievement. At any rate, I have the comfortable reflection, in the midst of the somewhat dispiriting connotation of ideas I have suggested, that I will furnish a neutral background to the cool air that is presently to come from solids with which I am surrounded. [Laughter and applause.] It is not often that we have the privilege of listening to an address from a presidential possibility. [Applause.] But if that great and glorious citizen, that exalted patriot, William Howard Taft [applause], fails of election, and that great and glorious citizen and exalted patriot, Theodore Roosevelt, fails of election [applause], I say that if these gentlemen fail of election, does it necessarily follow that it is time for a Wilson high brow? [Applause]. Not at all. Not at all. The Fifty-ninth Congress, in the exercise of the wisdom which sometimes steals over that body, has decreed, by a proper series of events, the incumbency of the White House in the person of the present Secretary of Commerce and Labor. [Applause.] We, who are interested in the success of business, would be glad to see in that exalted position, a gentlemen who has discharged the duties of his present portfolio with so much credit to himself and to the nation. The country could receive nothing but profit if a combination of circumstances arose that led him to the White House. [Applause.] I consider it a greater privilege to introduce to you, ladies and gentlemen, the Honorable Charles Nagel, of the Administration. [Applause.]

ADDRESS OF SECRETARY NAGEL.

Mr. Toastmaster, Ladies and Gentlemen: My official experience is somewhat brief and in many ways limited, but I think I am safe in saying that it is long enough and thorough enough to protect me against any of the insinuations which the toastmaster has just expressed. [Laughter.] Long distance suggestions and remote possibilities have no terrors for me. We are accustomed to be on the firing line, and if we don't see the guns across the streets, we take no notice of them. It has been intimated to me, and if it had not been intimated, I should have assumed it, that on an occasion of this kind, a guest is not expected to touch upon political questions. [Cries of hear, hear.] I appreciate the force of that suggestion, and I am not quite sure that you do. [Laughter.] Will you be good enough, any one of you, to tell me of a single subject which a man might discuss before an assembly like this, that is not related to politics? Will you show me any phase of life, industrial or social, that is not involved in the public discussions of this campaign? Therefore, if I were to obey that injunction literally, I would have to sit down. Further than that, if I were to obey that injunction literally, I would have to admit that I cannot talk about anything that is on my mind, because I must assume that I have been asked to be your guest because I happen to hold official position, and holding that position, I am necessarily interested in public questions and every public question necessarily has a political coloring. In other words, we cannot get away from political questions, however much we may want to. I might protest and say to you that the activities of this administration may be discussed with perfect safety. There has been very little partisanship in this administration. I might say to you that a president who has appointed two Democrats to the Supreme Court and made a Democrat Chief Justice of the United States can hardly be accused of partisanship. [Applause.] I might say to you that the platform upon which the President was elected, while for a time a partisan document, as a result of the election became the last solemn mandate of the people of the United States. [Applause.] And in enforcing that platform, the President and the Administration were doing nothing but carrying out the supreme will of the people. I might go on and say to you that that

platform has been carried out with supreme fidelity, and I could not be accused of partisanship. I might go on and say that the individual measures which resulted from that platform were, in large part, made possible by Democratic participation and in that way were deprived of all possibility of partisanship. I might say to you that the very measure which has been the chief cause of controversy and about which we hear so much to-day, the tariff bill, could not have been enacted if it had not been for the intelligent participation of Democratic senators who sought to protect their own states. [Applause.] Let's get away from self-deception. Of course when the measure came up, it was carried by a partisan vote and it had against it a partisan vote, but when the schedules were adopted when the heat of the controversy was on, when the bill was being framed, the Democratic votes made possible the adoption of the schedules of which the Democratic party to-day complains. There was no partisanship in that; it was not a partisan measure. But I will not discuss these things; I am saying to you that I might. I am perfectly prepared to take up any question and discuss it from a point of view that no Democrat and no Republican and no Progressive can evade. I know there is agitation throughout this country; there is agitation throughout the world; there is unrest everywhere, although it is to be noticed that the unrest in other countries has for its purpose the securing of a form of government similar to ours; whereas, in our country, the unrest seems to be actuated by a desire to destroy the institutions under which we have prospered. That's the question. I am not here to minimize. I recognize the power in many ways; I have welcomed it, because I know that things were not as they should be, and the question simply is, What is the trouble and how is it to be remedied? Sometimes I have said to myself, the chief trouble is to be attributed to the fact that we have too many self-styled patriots who entertain themselves and their friends by working the fog horn in fair weather. [Laughter and applause.] Now that is not what it was made for. The Lighthouse Bureau is in my department and I have been in Washington long enough to know what a fog horn is intended to do. [Laughter.] There is too much of a disposition to make us ashamed of the great things that this people have done and to teach us to rely upon the fulfilment of promises that never

can be carried out. That is the trouble. I think it's a confusion of ideas. I am perfectly persuaded that important things are to be done. I cannot deny to myself that great problems confront this country, but in my judgment, they are not political so much as they are industrial. In other words, the measures that the situation calls for in this country are not of fundamental political character, but they are of an industrial character. [Applause.] We don't need to change our Constitution. We do not have to change our representative form of government. We do not have to revolutionize our political system to awaken to the new industrial era and to find the measures to meet the conditions of modern industrial life. It is all a question of how far we shall go, and beyond that is the question, what part of our government shall deal with the problem, because we must bear in mind that we have a dual system of government and that some things are to be ordered and regulated by the national government and some things belong specially to the state government, unless we are prepared to destroy utterly the dual system under which we have so far proceeded. Of course, that is a great problem, and I know that you are not in the mood to listen to an exhaustive discussion, even if I were capable of it, of so broad a problem, but I think I can illustrate to you by a few examples of the activities of my own little department, what are the possibilities of legislation and what, in my judgment, the limitations of that legislation are. I have spoken of my little department. I don't wish to be unduly modest about it. Perhaps, since my term of office has nearly expired, I may speak about it with some freedom. The department is the youngest and, in the eyes of most people, the least important; in my own judgment, it is the coming department of the government [applause], and I would rather be at the head of it than any other department in the government. [Applause.] I will tell you why; because that department is on the firing-line of contact between the government and the people more than any other with the possible exception of the argicultural department. In that respect, they stand in the same position. With respect to the agricultural department, that situation is recognized throughout the land. With respect to the Department of Commerce and Labor, there is not one man in a thousand who appreciates the fact whose fight it is. It is largely yours, because that department

concerns you and all the human activities with which you labor. Let me tell you briefly. I don't believe there are a thousand men in the United States who could state the bureaus in that department and yet every one of them have to do with your immediate affairs. When Congress threatened not to make an appropriation some weeks ago, I said, "I hope they won't do it; I hope that, for a whole day, there will be no appropriation, in order that the wheels of government might stop, because in no other way can the American people be made to understand and to feel how infinitely dependent they are upon the activities of the government for every hour of their lives." [Applause.] My department has an annual appropriation of about $16,000,000. That is not much when you talk about a billion dollars, is it? Out of that, I collect, in the department itself, from $5,000,000 to $6,000,000 and turn it into the Treasury. In other words, there is not more than about $10,000,000 or $11,000,000 appropriated to that department out of so-called revenue collected by taxation. That is not much, is it? Now, let us see what bureaus we have. We have the Coast and Geodetic Survey, which makes all the soundings and all the charts of the Navy and Merchant Marine at home and abroad. We have the Navigation Bureau, which makes all the regulations for shipping. We have Steamboat Inspection. We have the Lighthouse Service, the Census, Fisheries, Standards, Immigration, Labor Bureau, Corporation Bureau, Manufactures, Statistics and the Children's Bureau; thirteen. That looks as though we might have something to do, doesn't it? I have one assistant secretary and we are expected to supervise that whole business. I have asked people, "How many employees do you suppose we have in the department?" The usual answer is five hundred. I say we employ nearly five hundred men at Ellis Island, one single detention station of one bureau. In the Bureau of Immigration, we have anywhere from 10,000 to 13,000 employees. When the census was being taken, we had in our department 83,000 employees at one time. Figure it up and see what becomes of $16,000,000, and figure furthermore what it means to have several hundred ships in commission, manned, to repair detention stations on our own property, that have been bought and paid for, and constantly make improvements and repairs. You can figure, as business men, what $16,000,000 amounts to with a force of that kind and

in that kind of work. How many people know that in my department there are some 300 or 400 ships actively engaged all the time, 12,000 employees, about 2,000 of them in Washington and the rest in the field or at sea? Why, not long ago, in the harbor of New York, when our Navy had one of its great reviews, I was invited as a matter of courtesy. I was on board the "Mayflower" with the Secretary of the Navy and a young man came up to me and said, "It's a fine sight, isn't it?" I said, "Yes, that's a fine sight, but I've got more ships than that." He looked at me and walked off to some people and said, "That fellow's daffy, isn't he?" "Well," they said, "you'd better go back and try him again." So he came back and said, "What do you mean?" "Well," I said, "I have in my department a great many more ships than are here, so and so many hundred, actually employed." I said, "If I could get the ships in my department assembled and have a picture taken of them and have it published in the papers, the people of the United States would get some impression of the activities of this department." He said, "That's a brilliant idea; why don't you do it? We'll take it." [Laughter.] I said, "I guess you would, but we are busy." [Laughter and applause.] "As long as the Navy is on parade, we have something to do; when they get busy, we go out of commission." [Laughter and applause.] I don't mean that we don't want a Navy. I want the Navy there, so that we can keep busy. But this is just by way of a generalization. There are two or three bureaus in the department that are immediately suggestive of what is now proposed, what is promised, and where, in my opinion, the limitations are. Take, for illustration, the Bureau of Standards. Now, this audience must know something about the Bureau of Standards. I know the general impression is that the Bureau of Standards establishes weights and measures, and probably has some solemn standard of a pound stored away somewhere in a safe so that it cannot be tampered with, and a measure of a foot and a yard put away somewhere, so that nobody will make a mistake about that, and that is the extent of the activity. The Bureau of Standards has to examine practically all the material that is going into the Panama Canal. We examine all the material that goes into the Navy. If we were to collect from the other departments for the work that we do for them in examining materials alone, we would

collect probably $150,000 a year in fees. The Bureau of Standards examines the effect of heat, electricity and everything of that kind. You ought to know. It is now probably up with the best bureaus of similar character in the world. What does that mean? It means that the demand for higher integrity in public life has found practical expression; it means the next step to the honest dollar. We have had one great national fight over the integrity of the dollar; there's no reason in the world why we shouldn't have a national fight over the integrity of the pound and the foot; not a bit. [Applause.] If my dollar is honest, I want to get back an honest pound and an honest foot, and if I get back an honest pound, I want the goods to be honest and I want the label to be honest [applause], and I want every declaration made with respect to those goods, I don't care whether it's on the bottle or the package or in the newspaper, to be honest. That's standards. [Applause.] I am in favor of the modern idea; I welcome the unrest. I think that the demand for better standards was timely, but I believe that we must not lose our strength in indulgence in vague dreams. We cannot live in pure altruism, but the demand must find practical expression, and my Bureau does express it. How is it to be enforced? That presents the other question of the dual system. Only one government can establish the standards and that's the national government, because they must be uniform throughout our country, at least, and if the International Congress of Chambers of Commerce in Boston amounts to anything, as I think it will, the demand for standards as to money, paper, checks, bills of lading, pounds, measure, quality, everything, will be extended to the international commerce of all the world. [Applause.] That is what they are striving for. But suppose the national government has established the standards; who is to enforce them? That depends upon you. If the state authorities do not enforce them, that will be the end of it, and we are doing everything we can to induce the state authorities to employ our standards and to insist upon them. The first year I was in Washington, we invited the Commissioners of Weights and Measures of the states to come to Washington for a conference, and I think we had fifteen present. Last year we had seventy-five delegates from different parts of the United States—as enthusiastic a body as you ever saw, eager to enforce the standards that we

have put into their hands. That is what I call intelligent co-operation between the national and the state government under the dual system as the Constitution has provided. But if the states should fail, nothing in the world will stop the national government from pursuing the enforcement of the standards which it has fixed. The national government will say, "In the nature of things, the Constitution gives us the power, we fix the standards; we don't do it for fun; if they are not enforced, we propose to see that they are enforced," and it will be another instance of the gradual encroachment of the national authority in a field that might have been employed by the state, but that is lost to the state by the failure to exercise the authority which it has. [Applause.] There you are. Now, come to the Bureau of Labor and the Children's Bureau; that represents the other extreme. Those two bureaus are authorized to make the fullest possible investigation into the conditions of the wage earners and the children. In a way, the two bureaus complement each other, because the Bureau of Labor had the power to make many of the investigations that are now left to the Children's Bureau. Extensive examination and investigation have been made. Volumes and volumes have been published to show the conditions under which, in different states, children are employed in mills, etc.; to show under what conditions men are employed in steel mills, and the very force of publicity has remedied many things. But somehow, it seems to be lodged in the public mind that, because the United States has the authority to make an investigation, therefore the United States government ought to afford the relief for every condition which it has exposed. In my opinion, there is a fallacy in that proposition. It stands to reason that the national government should make the inquiry, because, if the report is to be of any value at all, it must come from some central power; the investigation must be made in all parts of the country upon the same basis and upon the same lines, so that the statistics may be intelligently compared and acted upon. That goes without saying; but it doesn't follow that the facts and conditions which the Federal government exposed in these reports must necessarily be relieved by congressional action. On the contrary, I, for my part, seriously doubt the power of Congress under the existing Constitution, to afford that relief. I am sat-

isfied that it was never intended that the Federal government should go beyond measures that pertain to interstate commerce. I am satisfied that it was never intended that Congress should invade the life of the individual man, woman and child of the state and prescribe how they shall labor, how they shall live, how they shall be educated, and what should be done in any fashion in that respect. That was the divding line between Jefferson and Hamilton. Hamilton was the Federalist, who saw, in his imagination, the vast development of this country; who realized the need for Federal authority to regulate these vast interests. It was Jefferson who was the individualist, who insisted upon the right of the man to live with as little legislation as possible, and who dreaded the day when the Federal government, by an assumption of authority, might encroach upon the state and dictate to its citizenship, how it should live and labor. I know that at the present time, in public discussions, it is assumed without argument that the Federal government has the right to do all these things. We are told that a minimum wage ought to be fixed, and, while nothing definite is said, the inference is that the Federal government is to do it. You gentlemen know what that means. If the Federal government once assumes to fix the minimum wage throughout the United States, you know that no Congress can act intelligently upon the varying conditions of the different localities; you know that fixing a minimum wage is a humbug on its face, because a minimum wage, without fixing the price of the goods to be bought with it, is nonsense. [Applause.] It is not dealing honestly with the wage earner—and he is entitled to the truth. I have always found that there is only one way to deal with men and that is to come right out frank and tell them what the difficulties are. [Applause.] You know, gentlemen, and every man who has ever read history knows that, if the Federal government once assumes the power to fix the minimum wage, it will not be long before it will be called upon to fix the maximum wage. You cannot accept protection without paying a price for it. You cannot yield to guardianship without becoming a dependent; and, while I know there is no such thing left as pure individualism, while I know that we have had to modify our old ideas, there are many men who cannot keep up with the procession, who fall out of line and must be given support, still I maintain that

we should resist this trend to have the government do everything for everybody who hasn't everything he wants. [Applause.] Now, there is another bureau in my department that represents the Federal idea. That is the Bureau of Manufactures and Statistics, the two now consolidated finally under the proper name—the Bureau of Foreign and Domestic Commerce. That bureau needs very little assistance from state authority, but it needs a great deal more support from Federal authority than it has so far received. Instead of talking about vague possibilities—I'd rather call them impossibilities—such as we have to listen to nowadays, promises that are made for immediate consumption and won't be heard of after the election [laughter and applause], I think it is high time for us to devote and for you to devote your attention to the need of constructive legislation pertaining to your affairs. You have had a good deal of attention, I think, in this country, but you have had it all on one side and that has not been the side that you would have selected. It has not always been comfortable; it has come a good deal in the nature of penalties. That is not surprising. We were a young people, a people of vast resources. When we got tired of one acreage, we found another equally virgin. We were self-centered; we were individualists; we dealt with all questions from the domestic standpoint. We dealt with international questions from a domestic standpoint. We could not train ourselves to believe that there were any questions pending that might concern somebody else. We are learning. It has been impressed upon us. We have got questions that concern other people, and we cannot pass as hastily over them and upon them as we have done in the past. The anti-trust law and the railroad regulation law were, in my judgment, the first proof of a recognition of the fact that we had an industrial question to deal with in the United States. Our Constitution had undertaken to protect us against political oppression. We had every possible safe guard against political oppression; we had the three departments of the government, the executive, legislative and judicial, and each was balanced against the other and the national government was balanced against the state government, and there was no perpetuity of office possible and the third term was not dreamed of at that time and we just thought we were perfectly secure. [Laughter and applause.] But gradually and by degrees it crept

upon us that industrial power might be just as great as political power, and we came to recognize that there might be such an accumulation of industrial power in a few hands, that it would be more arbitrary than any political power we had ever dreamed of. That was the question. I don't believe many men realized or were conscious of the significance of that movement. The framers of the bill probably were, but you know now, everyone of you will admit that, whatever may have been its inconvenience, railroad regulation was absolutely necessary for the simple reason that we were bound to have a rule of the game which everybody had to respect. [Applause.] It was not possible to have fair competition in those days. A man who would not accept rebates had to go out of business. No shipper was strong enough and no railroad was strong enough to insist upon a square deal. He who insisted upon it, no matter who he was, went down, and there was only one authority that could impose the rule of the game, and that was the government, and it did it. [Applause.] It was so with the anti-trust law. Of course, it laid dormant for a long time and then we pretended we couldn't find out what it meant, and a good many people didn't know what it meant. In my judgment, it was a perfectly plain proposition; it was nothing but an impression of the old common-law doctrine against monopolies upon the Fedéral statutes, and putting the Federal government behind the law. The individual states had tried to deal with it and failed for the simple reason that an individual state cannot deal with a national proposition, and every combination big enough to get attention was a national and not a state proposition. So one day, they had a big rumpus in Ohio and somebody got elected to office as a result of the rumpus he made, and when he got through with that, somebody else would start one in Kansas and all the big concerns would say, "We have to have some legislation against us somewhere all the time and that's part of the expense of doing business and the consumer must pay it." But nothing came of it and finally it became perfectly evident that this was a national proposition because it was national commerce and that there was only one authority which could deal with it and that was the Federal government, and it did it. People still say they don't understand what the decision means. I don't think it is so obscure. I think there are several safe rules to observe in life and one is,

when you are in doubt, decide against yourself and you are not apt to make a mistake. [Laughter and applause.] Another one is, that most large concerns know perfectly well when they are competing to get a customer and when they are competing to "get" a competitor. [Laughter and applause.] And that definition is just as definite as most definitions of wrongdoing that appear in courts of equity for judicial interpretation. You cannot find a definition of fraud any closer than that—or of deceit, or of mistake, or of accident. The moment you undertake to define it in precise language, you kill it. It is to be interpreted in the light of the conditions that are brought up; that is what a court of equity is there for, and the very attempt to nail it down in statutory expression beyond the general term, defeats its purpose and paralyzes the court in getting hold of the real offender. However, what I am interested in now—I am perfectly satisfied to let those laws stand—what I am interested in is the other side of the question, the constructive side. I think it is time, since the Federal government has said what we shall not do, to have the Federal government say definitely what we may do. [Applause.] There is no difficulty about it. When it was first suggested that the Federal government state in distinct terms, under what conditions organization might be had for interstate business, the cry against it was that it would be destruction of states rights. Well now, you know we have heard about states rights until we are almost indifferent to them. The fact is, that the states rights cry has been raised so often that states rights are apt to be lost in the shuffle. There are states rights and they ought to be maintained and they are maintained in some states, but strangely enough, the states that make the best use of states rights are in the North and not in the South. Massachusetts is the most tenacious employer of states rights in the United States to-day. Now, I assume that the state which undertakes to use its authority to do that for which it was not intended, not only defeats its purpose, but it paralyzes its own authority. I think the Federal government ought to be willing to say to an interstate organization, "You give us your prospectus, you define your purpose, give us your capitalization, give us the terms of your organization, and we will say to you definitely whether you stand or fall, and if you stand, you shall be protected as long

as you obey the terms of that prospectus, not only against Federal law, but against obstruction by state authority." [Applause.] Now, I know that is a bold statement to make, but I have given some thought to this and I am prepared to stand upon my judgment. I fail to see how you business men can survive the conflicting conditions under which you now operate. I stand in blank amazement and wonder and admiration of the courage you have to make investments under these conditions. Of course, I know there is great prosperity now. Everything is splendid. You can't get labor anywhere; according to my reports, everything is prosperous. They say government has nothing to do with prosperity, that the government doesn't make crops. Well, perhaps not, but I tell you this, bad government prevents them. [Laughter and applause.] And good government does give the confidence to make investments and to manufacture goods for future sale and to store them up for customers, and it does encourage the farmer to till the soil and put in the seed in the hope that the year after or six months after, conditions will still be as they now are. [Applause and cries of "Good."] Now I say, I admire your courage and I am not here declaiming against states rights. I am a states righter within the states jurisdiction and a nationalist within the Federal authority. I believe in the dual system. I believe that James Wilson was right when he said that the state must be left to do everything it can do, but there must be a national authority to do that which the state is found incapable of doing, and I believe that interstate, national commerce and international commerce are problems that the state is incapable of dealing with and that the Federal government must assume the authority to regulate and protect. It has regulated and been found the only authority fit for regulating it, and therefore it must be entrusted with its promotion and protection. You see what the condition is to-day. You know that in some states you would be punished for doing the things which in other states you would be punished for omitting to do. I believe one state says that if you don't compete you are guilty, but if you compete enough to hurt the other fellow, you are also guilty. [Laughter and applause.] Now, that is the finest definition of good and bad trusts I have heard yet. That is one of the things with reference to which no one can find out what he is intended to do, particularly when the state that

makes such a declaration, applies it not only to transactions within its own jurisdiction, but also predicates a proceeding in its jurisdiction upon things that have been done in other states. You can't stand that. Let's go beyond that. Suppose a corporation is organized in Missouri to transact business there, and undertakes to go over to Illinois; Illinois has a perfect right to say, "You shall not come." Illinois has a perfect right to admit that corporation and, after it has established its good will, bought property and got its main business in that state, expel it by act of the legislation—a perfect right. I admire your courage. You know that your good will is frequently your real capital, and yet, if you have an interstate business, any state has a right to destroy your good will within its jurisdiction, at its option. Beyond that, take your codes. St. Louis lies on one side of the Mississippi River and East St. Louis on the other; they are practically one commercial center. You have two commercial codes. What is negotiable paper on one side of the river, is not negotiable on the other; it takes two lawyers to find out what you are able to do. It pays us. [Laughter.] If you like it, we can stand it. Kansas City lies at the other border of a great state, competing with St. Louis and it is in all respects governed by the same commercial code as St. Louis, while East St. Louis, the same commercial center, is governed by a different code, and Kansas City, Kansas, just across the river from Kansas City, Missouri, is governed by another. Is there any sense in that? If we were not so almighty rich that we can stand anything, even the high cost of living, for instance, we couldn't stand such a system as that. Do you suppose that Germany could create her foreign trade with such an embarrassment at home and such a source of expense? It is time for us to begin to think about it. We need constructive legislation to advise us what we may do and to assure us that if we do do it, we will be protected. We need it at home and we need it absolutely abroad. Three miles away from the coast, the state has nothing to say; the Federal government alone creates and controls. Where is the merchant marine—if we are ever to have one, and I trust we may some day—[applause], if we ever have one, where is it to get a charter? From New Jersey? New Jersey has charters enough now. [Laughter.] And after the Merchant Marine Company has started with a charter from New Jersey, suppose Governor

Wilson changes his mind and New Jersey takes the charter away? What happens then? Is the Federal government to depend upon an agency like that? A merchant marine under a state charter, which any one state out of forty-eight, may deprive it of the right to serve the Federal purpose. Why, it is an atrocious proposition! The diplomatic service opens the door and creates the opportunity for you for export trade. You avail yourself of it. You can't get a Federal charter, you have no Federal authority, you have a state charter, and after the opportunity has been created, you make use of it and everything goes on swimmingly. Your state begins to litigate against you and takes away your charter and the Federal government is left empty-handed. Does it stand to reason that the Federal government will let one of its departments create the opportunity and then be laid low by the act of one state, when it has the Department of Commerce and Labor, which is all labor and mighty little commerce? [Laughter.] That's the situation. Germany, Great Britain and France promote these interests intelligently. The Board of Trade is a member of the government. You can't get through a schedule in a tariff measure without having the advice of the Board of Trade. You cannot get through a measure to promote trade in a particular country without getting the endorsement of the Board of Trade; the minister is there for that purpose. And if you have a nice case of competition where you want to beat a competitor from some other country, you put your thumb on the common carrier and say, "Here we like equal rates, but when we are competing with another country, you'll just lower them in this instance so we'll get that job." You know that's true, and still they tell us that in this country we don't need a merchant marine, because the foreign ships serve us as well as they do foreign countries. Do you believe it? I don't. It isn't natural and it isn't true. Their system is the other way. They do make their carriers bend to the necessities of their cases and they are not ever going to give us the advantage of the same rate if we are in the field. We need a merchant marine, if for no other purpose than to put us on a basis of equality. We have got the system at home of regulating railroads absolutely for everybody, but the moment we leave the shores of the United States, we leave all the regulations to our competitors. Does it work out? Now, isn't it a dream? We

are revising our tariff. There are great changes made. Any man who will read the list will know that the free importations have greatly increased and they are liable to increase still more. We must have export trade, but we cannot have export trade as we deserve it, in the full measure, unless we have the agencies by which it can be carried. Tell me we don't want to do this, that and the other thing? I say, "Well, I'm willing to go slow." We can register foreign-built ships now; we have got that much through. We can get material for ship building into this country free. Those are the things we were told to rely upon; we are going to rely on them now; but if that don't accomplish it, what are we going to do next? Starve on theory or thrive on practice? I believe that we need not do as other countries are doing, but, if we don't want to do that, we must invent something else that will compete successfully with them, and, unless somebody can show me something better, I am going to do what the other fellow is doing to compete with him. [Applause and cries of "Good."] I am not going to be frightened by terms and by words. Now, to come back to the Bureau of Manufactures—I know I have spoken too long, but a man can't help it when he gets started upon a subject of this kind—coming back to the Bureau of Manufactures, which is created for the promotion of domestic and foreign commerce. That's your department. I don't know what the appropriation for the Department of Agriculture is—about $18,000,000, I believe. The Bureau of Foreign and Domestic Commerce, in which you are interested, has an appropriation, I believe, of $150,000. That's about as much as the German government pays for its Consulate in New York. [Laughter.] That's the modern idea. I fail to see why you do not assert yourselves. That's your bureau. That's the Department of Commerce, and that's the only bureau that entitles that department, strictly speaking, to that name. What you want to do is to organize. Demand $500,00 or $1,000,000 for special agents traveling all over the country, gathering information. Consular offices get a good deal of information, but consuls are diplomatic officers in a large measure and cannot always get the information we want. They are not free lances and dare not be. We need free lances. Other countries have them. You want to be consulted as to the men to be appointed, and send them out and get the information and get

it back to you as quickly as you can. You know there have been great improvements in consular reports, but the scope of a consular report is limited, it is not what you should have. Your opportunities are there and you must avail yourselves of them now. We are just finishing the canal and everybody else seems to be ready to use it but ourselves. [Laughter and cries, "That's right."] That's a serious matter. You know that the man who first establishes his custom is the man who is going to keep it for a long time, right or wrong. You know that there is a power of mere stability that sustains a relation with a customer. You know that you may have an old machine and a new invention may come in, but that new invention has got to fight for fifteen or twenty years, no matter what the capital behind it, to unseat the established thing. That's true. Isn't it so with business? You know that the man who has the customer—you've got to have something more than better goods, somehow, to unseat the man who has already got the customer, and you know, furthermore, that a good salesman can sell poor goods sometimes when a bad salesman can't sell the best ones. That's true. [Applause.] That's another argument for a merchant marine. We talk about South American trade. We are on the best possible terms with those countries. We compliment each other; we express confidence in each other. We have the most pleasant greetings; we promise all sorts of things; but Germany does the business. Why? Because German ships sail into their harbors under her own flag and we don't. Secretary Root, after he made his trip, said that the only American flag he saw on a mast was that on the man-of-war that took him down there on a mission of peace. [Laughter.] Those people will never believe we have come to stay until our goods go into their harbors under our own flag. They say, "When your goods are delivered to us from your own decks, then we know you have come to stay and we can tie up for permanent business." How are you going to do it? You have got to organize. You have done it already in Buffalo. You know you have got one Board of Trade here and we can say of Buffalo what we have said of Boston, that when the Board of Trade speaks, we know Boston speaks or Buffalo speaks. You have got a great many large cities that have three or four Boards of Trade and Business Men's Leagues and all sorts of organizations, and

you can get four telegrams a day from them and no two will agree. You want to organize your business in your city and organize Boards of Trade of your state and you want to organize your Boards of Trade into the Chamber of Commerce of the United States, which has now been started. Then you can speak. Then the different branches of the government may refer to you questions in anticipation of trouble with respect to rules, laws or legislation. Then the executives of the different departments may speak intelligently and say, "We have conferred in advance and this is what the business men need;" not special legislation for the protection or advantage of this or that man or concern, but general legislation for the promotion of the entire commerce of the country, to give everybody an equal chance. [Applause.] Of course, I know I have exceeded my time and I apologize to you. [Cries of "Go on, go on."] No, I mean what I say; I know I have spoken too long, but this is a serious subject. I am not a business man; you can see that for yourselves and can hear it from me. I am only a western lawyer; but I tell you sometimes a little imagination and interest will help a man to see a good many things, and I am profoundly impressed with the difficulties under which, in my judgment, the large concerns and the men who do large business must labor in this country. I have become almost infatuated with that question, and to me it will make no difference whether I am in office or out of office, I have become so interested in that matter that I propose to continue pounding away at it as long as anybody is willing to listen to me. [Applause.] I believe in my country, as I said once before to-day; I believe in our institutions and in their preservation essentially in their present form; I believe in the great men of our country and I refuse to be ashamed of the great things that the energy and enterprise of this country have accomplished. I, for one refuse to look upon the dark side and see only our mistakes. I want to turn away and look at the great things that have been accomplished and I want the old word to go out again of pride and confidence in the business enterprise and progress of the United States. [Applause.]

THE TOASTMASTER: Our next speaker dwells in East Aurora. There he draws from the Pierian Spring of his wit and imagination to fructify the arid intellectual wastes of that town. [Laughter.]

Oft has its stubborn gleve yielded to his persuasive herald, but when that herald throats, as it will, a truth from time to time, he comes to Buffalo for rest and recreation. The herald is out of business to-night and we are glad of it because it brings our next speaker to us, and he is glad to be here. It is the first time that I have had the pleasure of sitting at dinner with this gentleman. It must be quite patent to a casual observer that fate has intended to bring us together because we constitute in ourselves the original "Before and After Taking" sign. [Laughter and applause.] I have been accustomed to meet him at the barber shop where I resort for the purpose of having my shoes cleaned. [Laughter.] He goes there to arouse the passions of the gentlemen who practice their quiet craft there. Him they receive with impeccable resentment, but me with compassion. [Laughter.] The author of an English classic that has been translated into all tongues, whose pages are lighted by the sun throughout its orbit, poet, wit, man of affairs—we shall take pleasure all of us, in listening to Mr. Elbert Hubbard. [Applause.]

ADDRESS OF ELBERT HUBBARD.

Mr. Toastmaster, Mr. Nagel and Gentlemen of the Allied Foundrymen's Association: Not long ago I was in the City of Chicago on my way to the West and, having a few hours to spare, I went out to the University of Chicago. There is a boy out there from our town, the beautiful town of East Aurora; and do you know, this boy is no good around home and so we are sending him to college. [Laughter.] He is too lazy to work, and so they are going to make a lawyer out of him. [Laughter.] While I was out there, the boys introduced me to a very learned man. They said he was one of the most learned men in the world. They said he had written books that nobody understands [laughter], and they wanted me to meet this man. They said we had something in common. [Laughter.] He was a high brow and a high brow is a man who knows everything but the obvious and can do everything but make a living. [Laughter.] And do you know, when I met that great man, I was a little embarrassed. I am from the country. I am a farmer. I am a farmer with a literary attach-

ment, and I didn't know what to say to that man, but it came to me all at once—a little good advice given to me by Brother Miles years ago. Brother Miles said, "If you are out with very larened people and you don't know what to talk about, talk about electricity." [Laughter.] "Then you will never shock anybody." And so Brother Miles said, "If you don't know what to talk about, talk about electricity. Just say 'speaking of electricity'—Of course it makes no difference what you are talking about, but say, 'speaking of electricity,' it is the great mystery; nobody knows what it is; all we see is its manifestation—you are perfectly safe in saying that at any time. Of course if you don't know anything about electricity, you will have to back up and side-step and start something else, but usually it's all right to say 'electricity is the great mystery, nobody knows what it is, but all of us see its manifestations!'" And do you know I was just going to say this, when all at once he said it. [Laughter.] He beat me to it. "Good-bye," I said; I ran down the steps and caught a trolley car. I jumped on the front end, and over the head of the motorman I saw a sign "Don't talk to the motorman," and this suggested an interview. So I said, "Partner, what is electricity?" "It's the juice," he said. [Laughter.] He knew. He says, "It's God's best gift to man." I said, "I thought woman was God's best gift to man." "Same thing," he said. [Laughter.] He says, "It's the great mystery; nobody knows what it is. It's very dangerous if you don't know how to handle it." [Laughter.] "Now," I said, "does it make this car go?" "Sure," he said. I says, "Tell me how." He told me. I didn't know before and I don't know now. [Laughter.] I says, "How do you know so much about this?" He says, "I am taking an International Correspondence School Course." [Laughter.] He says, "I get $65 a month for holding down this job. I am going to have $125 next month. I will have charge of the electric light station." I says, "I get off there at the corner," and he stopped the car within a foot of where I wanted to get off. I said, "Good-bye, my friend." He said "Good-bye, old man;" but do you know he never even looked up at me; he didn't know that I am one of the great literary lights of the world. [Laughter.] He didn't know, and neither did he give a damn. [Laughter.] He was just intent on getting me off on terra cotta and carrying that car through in

perfect safety; and, as the car moved away, I said, "There goes an educated man; he is on to his job." If you do not like that definition of education, then take the definition of President Eliot, of Harvard, who says that that man is best educated who is most useful. [Applause.] We have a new definition of education. There was a time when educated men did no work and the men who worked did no thinking. The result was that both the thinking and the work were illy done. We will never be a civilized people until every man has an education and every man works. I believe in work. The difference between me and Brother Nagel is that he talks about labor and I do it. Now, this country has had two great presidents. The probabilities are that we will never have another. [Laughter.] I don't think that Brother Nagel will ever be President of the United States. I think that was taffy [laughter] passed out by our dear friend, the toastmaster. It is not likely that we will ever have another first-class man president. I do not want to crush your hopes, Brother Nagel, but that's my opinion. Now, you say you are not a business man, but on hearing you speak, I am refreshed and hope springs anew in my heart. If you are a lawyer, you have reformed. [Applause and laughter.] Now, you are a common sense man and I like you first-rate. [Laughter.] There are two kinds of lawyers and you are the other kind. [Laughter.] I was over in London a few months ago and I was invited to a banquet, and seated next to me at this banquet was the Earl of Yarmouth, your old college chum, and we got into a little argument on Socialism. We argued the case pro and con, mostly con [laughter], because I am from East Aurora. [Laughter.] And do you know the Earl made a criticism on affairs in America that struck me as pretty good. He says, "In America, you know, you have no leisure class, you have no leisure class." I says, "Yes we have; we call them hoboes." [Laughter and applause.] And do you know he smiled and I smiled; but I knew what I was smiling at and he didn't know. He says, "Very droll, very droll." He says, "Most amusing, most amusing; but," he says, "what is a 'obo?" I says, "It's a wind instrument." [Laughter and applause.] He says, "Most extraordinary, most extraordinary, but really I don't understand what a 'obo is." I says, "You are one;"—only I said it to myself. [Laughter.] The point was too subtle for him. I knew he would never see it

and I do not cast my jokes before swine. But it just came to me all at once that he was a well dressed, educated hobo; he lives on the labor of other men, on the labor of men who are dead, and I do not differentiate between the well-dressed hobo and the one who has achieved a tomato can. There's a certain amount of work to do in the world and some people have got to do it; and the reason some of us have to work from daylight to dark and the work is never done, is because some others never work at all. I believe in the man who works. I believe in the business man. I believe in the man who looks a pay-roll in the eye. [Applause.] My heart goes out to you. We have in this country one-sixteenth of the population of the world and the United States has one-third the wealth of the world, and we didn't get our wealth by annexation or by exploitation. We got it through the prayer of labor; and there is one prayer that is always answered and that is the prayer of labor. There are five sources of wealth: the farm, the factory, the mine, the forest and the sea. I believe in commerce. I do not use the word commercial as an epithet. I am a commercial man and I am in business for my health. [Laughter.] And the man who is not in business for his health won't have very good health and won't have much business. [Laughter.] Now I want to tell you just a little story for the benefit of your toastmaster. A few weeks ago I was in Wichita, Kan., and I was dispensing the caloric there gathered from my vacuum, and I wanted to catch a train at six o'clock for Hutchinson, Kan., in the morning. I left word for them to call me at 5.30. I was at the hotel right opposite the station. I happened to wake and look at my watch and the Waterbury said that I had six minutes to dress and catch that train. Well, I made it. I jumped into my clothes and crammed my belongings into my valise and ran across to the station, pushed past the man at the gate and jumped on the rear of that train just as it was pulling out. I settled myself in a coach, congratulating myself that I had caught the train. Just then the conductor came in from the other end and yelled "Tickets, everybody!" his lantern on his arm and in the dim gray light of the early morning. I reached into my pocket. I had no pocketbook! I had left it under my pillow! [Laughter.] I looked at the man and said to myself, "Can I explain it to him?" I sized him up. He had a mouth like a catfish, and when he got down within about six feet

of me, I said, "It's all off." I grabbed my grip and ran for the rear end of the train. The brakeman caught me by the shoulder and pushed me back in. "Where are you going?" he asked, "Are you bug-house?" I said, "They say I am, but I want to get off. I have no money and no pocketbook and I can't explain it to that man." He says, "We are going twenty-five miles an hour. You take your seat." He pushed me into a seat and then I looked around to see if there was someone in that car that I knew. I couldn't see a soul I knew; and finally I saw the badge of the American Foundrymen's Association gleaming in the buttonhole of a little fellow right opposite me. His derby was tipped over one eye and his cigar was pointed to the northwest, and without a second thought I reached right over and said to that man, "You loan me five dollars." He put his hand up to his ear. I saw he was deaf. [Laughter.] He says, "What did you say?" I said, "Loan me ten dollars." [Laughter.] He said, "You said five before." [Laughter.] I says, "Never mind; I'm up against it." "All right," he says, and he pulled a big greenish wad out of his pocket, skinned off ten dollars and says, "There, take it; if there's any change, get your hair cut." [Laughter and applause.]

THE TOASTMASTER: When that sweet singer, the American poet, James Whitcomb Riley, died he left a worthy successor in a Buffalo citizen whom we shall have the pleasure of hearing next. I commend his product to you Foundrymen; it is free from silicon and it is high in phosphorus. Mr. John D. Wells. [Applause.]

MR. WELLS.—Mr. Chairman, Mr. Nagel, Ladies and Gentlemen: I don't know why I have been asked here to-night to peddle my poor wares among men who have such greater wares to peddle. Perhaps that very discrepancy is the reason. Perhaps in the few jingles and stories that I have recorded, you may find the very thing that, in your rush of business, you have forgotten. I don't believe that there is any man so big in business but that he will pause and listen when somebody strikes a minor chord, sometimes. I firmly believe, too, that seventy per cent of the big business men were born and raised in a little country town, somewhere. I think you started from there, marshaled your genius and entered your field of endeavor, and solely on that theory I have prepared

a little continuity of verse and story to-night that will occupy about ten minutes, not more, entitled "Back Home Again With You," wherein I hope some of you gentlemen will recognize old friends and old faces. Now in going back home, we have got to be diplomatic. We have been learning a lot of hifalutin ways in the city; this high handshake and all that sort of rot; we have got to drop that right here or you are going to be talked about. These folks knew you when you didn't have enough clothes to flag a hand car, and you can't come back and lord it over them. You can't sandpaper your R's either; you have got to be your plain, simple, homely self and greet them in the good old fashioned way, "Howdye."

Mr. Wells then recited extracts from his poems, beginning with the one entitled "Howdye" and all of them were received with the sincere admiration of those present. It took them all back home to the olden days on the farm, when they were little bare-footed fellows.

Mr. Wells received the thanks of those present in the shape of a spontaneous ovation at the close of his admirably rendered selection.

A FURTHER CHAPTER ON FOREIGN VISITORS IN OUR PLANTS.

By the Secretary.

Those of us whose duties bring with them much correspondence from over the ocean, and who get to know many of the good people there personally, naturally are the recipients of introductory letters presented by foreign gentlemen who are desirous of visiting our advanced institutions and establishments.

The secretaries of associations naturally come in for most of these requests, and as the industrial countries of the world are constantly enlarging their respective fields of activity, there is an increasing tide of foreign visitors coming to our shores to study our industrial conditions and advancement. So far these visits have been very one-sided, our people being too busy to look for themselves what foreign nations are doing. We are, however, beginning to awake in this direction and it looks as if a greater business acumen is being displayed in our foreign relations on commercial and governmental sides. We are noting with concern that the advantages of Industrial and Continuation Schools in their ultimate effects on foreign commercial development have all been gathered by European countries, and we are badly handicapped in extending our energies outside of our tariff wall.

The writer remembers very vividly while walking in the streets of Chihuahua, Mexico, being stopped by a gentleman who remarked in German, "Well, you are the forty-third. Welcome to our city." There were forty-two German business men there, who practically controlled the wholesale as well as much of the retail business of the entire Province. On being informed in his own language that your Secretary was a good American-born citizen, with Wisconsin as his native state, and though an admirer of all that is good in German character and achievement, he considered himself lucky to be born under the Stars and Stripes, this good German was much disappointed, but friendly just the same. The incident will show how keen the foreign business

man and how clannish he very naturally is, considering his training and traditions.

When pushing into the markets of the world, the foreign manufacturer can give us any number of points. He starts modestly. He sees what others with whom he may likely have to compete are doing—hence his visit to our works. His government aids him in every way—even with bayonets in remoter regions. Ship subsidy, consular service, trained experts sent quietly looking for openings everywhere. Once he has established himself, adjusting himself to the customs of the country—even marrying into the best families—his trade cannot be displaced even by better lines of goods from us. This is right and proper, and if we do not profit by such experience, it is up to us.

Now, however, that our manufacturers are waking up, they also want to see what the nations which have captured trade that, commercially speaking, should come our way are doing. And when they go to the other side they find fine people, but by no means the open door that characterizes us here for the most part. The European manufacturer, with few exceptions, is used to a narrower way of doing business. He must consider the pros and cons of a line of policy much closer than we, and hence very frequently his decision not to admit a visitor, even if the refusal is given in the most charming manner. It may be remarked parenthetically here that we have plenty of manufacturers—particularly in the chemical and metallurgical industries—who are just as close as they are in Europe. Investigation of the history of these plants will usually show European born proprietors and European trained technical staffs as having outlined existing policies. The American is by nature hospitable in the extreme. He also knows that if he has something new, the visitor is not usually in position to pull down his plant and rebuild on the improved lines he may see. If the American is wise, he will welcome his European visitor and discuss points of practice with him. Both will be the gainers thereby. Those of our members who have received foreign visitors with letters coming from this office will have noticed that reference is made to the specialty the visitor is expert in, and that it is advised to take advantage of this. Further, of recent times these letters will have contained the clause that the visitor has expressed his

willingness to extend reciprocal courtesies in his own plant. On this hangs the purpose of this pamphlet.

Knowing the disinclination of foreign manufacturers to open their plants to visitors, several gentlemen, friends of your Secretary, who also receive numerous foreign visitors with letters of introduction and are expected to open the doors of American shops for them, have for some time insisted upon the promise of reciprocal courtesies before giving the necessary credentials. Your Secretary has many times, in meeting the prominent manufacturers of the country, listened to bitter complaints on the lack of reciprocity existing in this respect, and hence when one of our greatest manufacturing corporations, members of our Association, desiring to build new works here and wishing to study the latest advances in the art, sent a commission to the other side—armed with letters from this office and elsewhere—and found the doors closed to them, your Secretary thought the time about ripe to ask for concerted action looking toward a uniform method of helping the foreign visitor to see here what he wants to when he is willing to reciprocate, and help keep him out when he declines so to act. In plain language, to help the industrial gentleman, and to keep out the industrial pirate.

The consequence was that the following circular letter was addressed to the offices of fifty-two societies of an industrial and technical nature, whose secretaries were thought to be somewhat in the position your own was. A large number of replies were received. Where the matter was as acute as with us, it was taken up by the respective boards and acted upon either in full accord with the suggestions made, or partially so. Others were non-committal, and still others not interested. Here is the letter in question:

AMERICAN FOUNDRYMEN'S ASSOCIATION

OFFICE OF THE SECRETARY

WATCHUNG, NEW JERSEY, JULY 1, 1912.

To the Secretaries of Our Engineering and Technical Societies:

Greeting:—The undersigned, Secretary of the Foundrymen's Association, respectfully requests your kindly consideration of the following situation, and would be indebted to you for advice on what might be the best method of handling the matter in an effective way.

For many years representatives of the European Iron and other interests have been coming over to this country, accredited to many of our Secretaries of Engineering and Technical Associations. They have been well received, been given letters of introduction to the advanced establishments and show places of the country. They have found the doors open, information freely given, have gone home loaded with blue prints, sketches, figures, etc., and have consequently made a trip to America, to study its industries and development, a big feature in the business education of our foreign industrial brethren.

The writer may say that for a dozen years he has thus received from one to a dozen people monthly and sent them on rejoicing. He was always glad to exchange information on technical and commercial questions, and has made many warm friends on the other side of the world.

The other side of the story is, however, not so pleasant. On occasion, our American friends ask us for letters to the other side. They also want to see what is doing. We give them introductions to the Secretaries of Associations similar to ours, and these gentlemen, realizing the situation, do their best to open the doors of industrial establishments for American visitors. The success of this endeavor is nearly always problematical, and the result is that foreign visitors become fully informed concerning our progress, and we get left.

A peculiarly aggravating experience on the part of the representatives of one of our leading industrial establishments—the doors of which have always been open wide to foreign visitors—when in Europe a few weeks ago, is the direct cause of this circular letter. The following course of action is respectfully recommended for your consideration, and advice will be gratefully received.

1. To obviate the clerical labor involved in getting out a series of letters of introduction to applicants from other countries intending to visit our establishments (supposing them to have been properly accredited to us in the first place) but one general letter of introduction to be given, this to be retained by the holder until he finishes his tour.

2. No general letter of introduction to be given unless the applicant brings with him an official assurance that the European establishment he represents will be open to inspection for American visitors in return.

3. That letters accrediting visitors to our Societies should come preferably through the Secretaries of our European Sister Societies.

In view of the disagreeable experience of Americans in search of information in Europe, in return for courtesies extended here, the writer deems it a matter of justice to our industrial life that a fixed rule be adopted by us to care for this problem. It seems to be necessary to broaden the policy of European industrial establishments in this direction, and this can be done in no better way than to insist upon reciprocity.

Will you therefore kindly let the writer know whether you coincide with the above suggestions, or would modify the plan proposed? Also whether

you approve of giving the matter sufficient publicity to make it effective? The writer would gladly undertake this if found desirable.

This circular letter goes to the offices of fifty-two societies who should have the same problem to meet. Your reply is respectfully awaited.

Cordially yours,

RICHARD MOLDENKE, *Secretary*.

Among the replies a few will be given in part, to show sentiment prevailing. Beginning with those who approve to those who condemn.

From a large engineering society:

. . . The Board of Direction discussed this matter . . . endorses the course of action you propose and stands ready to co-operate with you in securing the same courtesies to American visitors in Europe that are extended to Europeans visiting this country.

From another large engineering society:

I am further requested to advise you that the members of the Board agree in general with your ideas as presented in your letter.

From a national engineering and industrial society:

The Secretary was instructed to issue such letters of introduction only to applicants who are prepared to present official assurances that the European establishments which they represent are willing to reciprocate such courtesies by the admission of American visitors to their works.

From another national engineering society:

The Board agreed that we would follow as closely as possible the stipulations you suggest.

Two other large engineering societies have approved of suggestion No. 2 of the letter in question, as best calculated to solve the problem.

All the above are board actions, the secretaries having presented the circular letter. In addition perhaps a dozen letters came from the secretaries of societies who did not think it necessary to present the matter to their governing bodies, but who heartily endorsed the suggestions and desired to learn the result of the inquiry and hoped for a standard form of letter which could be used for the constant requests they were receiving.

Now the other side. From a society of Foreign-American engineers:

. . . regret not to be able to take the matter up.

For which we certainly cannot blame them. The letter of your Secretary was sent, however, in a spirit of fairness to foreign technical men residing in this country, so that there might be no misconception on the subject. The Secretary of that society also wrote quite an extended discussion showing that we were just as bad over here—and for his particular industry he was right, for not so long ago it was a life and death struggle for existence between the European and American industries, as the competition was so keen. And probably that is the reason why in some lines of industry, notably the machine building trade, where patents and the tariff give monopoly, and inventive progress is so rapid that everyone here and abroad can afford to keep his shop open to visitors, there is no issue whatever existing. On the other hand, that much bitterness is present is shown by another letter received in which it says: . . . "and refuse absolutely to allow them the privilege of learning to conduct a similar business without having to go to the expense of . . ."

As the crowning instance of an extreme view in opposition to your Secretary's request, and in fairness to our membership who can thus judge for themselves whether the request was fair or not, the following editorial in the *American Machinist* of October 17, 1912, is given in full herewith:

A MISGUIDED REQUEST

A short time ago the secretary of one of the large manufacturers' associations of the United States addressed a letter to 52 engineering and technical societies in regard to foreign shop visitors. He draws two pictures:

The first shows the open-armed cordiality with which the American manufacturer recives his foreign brother, the manner in which the visitor is given information and the way in which he is sent home rejoicing, "loaded with blue-prints, sketches, figures, etc." The second is in strong contrast and pictures the American visitor asking for admission into a foreign shop only to "get left."

To meet this supposed situation, a course of action is suggested as follows:

(Here follow the three suggestions of the letter in question.)

This suggests concerted retaliation on the part of the great American engineering and technical societies under the guise of reciprocity.

Granting for the sake of argument that the alleged conditions exist in fact, we doubt the wisdom of any retaliatory tactics. The very spirit in which the association mentioned was conceived, and which is at the bottom of every association and society addressed, rebels at such a procedure. Mutual helpfulness has become the order of the day, and industry is now on too broad a scale to harbor any geographical distinction.

Again admitting for the sake of argument that the condition complained of actually exists, it is difficult to see how two wrongs will make a right in this or any other matter. Retaliation could have no other effect than to broaden the supposed gap.

But does such a condition actually exist? An answer in negative cannot be made too strong. Any thought as to how such an erroneous impression could take root in the minds of even a few is made unnecessary by the communication itself. It points out that a representative of a leading American establishment on a recent trip abroad did not meet with the same spirit that has characterized his own company's policy of the open door to all who desired entrance.

Here we have the basis of the misunderstanding. An isolated case, or a few isolated cases, are assumed to represent a general tendency. American interests can justly pride themselves on the passing of the closed-door policy in industry; but we have our isolated cases where a visitor, foreign or otherwise, is not made welcome. Would *we* not resent any general imputation, based on such isolated cases, that our policy of "give and take" extended no farther than our own borders?

Those qualified to speak with authority will at once stamp as absolutely unwarranted any accusation, direct or implied, that our European industrial friends are not meeting us on even terms in this matter. Any attempt to overcome a general condition that is purely imaginary can result only in injury to all concerned.

"There is such an abundance of evidence of a character that cannot be impeached, that the general European attitude toward American shop visitors is just as progressive and broadminded as our own, that any complaints to the contrary cannot be taken seriously. The mildest characterization of this amazing request is "misguided."

Here again we have the point of view presented. Who are "those qualified to speak" in the mind of the editor who wrote the above? Those who visit about in industries where you may not copy what you see without having a patent suit, or those who have patiently for years helped along foreign visitors in the belief that they were promoting international courtesy and upholding the hospitable traditions of the American nation? Let it be said

here that there is much that is not pleasant connected with this effort. At the recent Congress of the International Society for Testing Materials, many of us were asked for introductions to the establishments of the country—which we gladly and freely gave. To our delighted astonishment later on, we received official communications from the gentlemen and even from the ministers of their governments, thanking us for the courtesies extended. This is so rare that it deserves publication here. Your Secretary only the other day assisted the president of one of Europe's large industrial establishments with letters of introduction, which had to be sent after him. They were used all right, but not even acknowledgment of their receipt was had. At least thanks could have been expected.

The editor of the above editorial charges your Secretary with suggesting "concerted retaliation . . . under the guise of reciprocity." He had thought that his habit of doing nothing under a guise, but hitting openly from the shoulder at all times, was pretty well known. However, whether "the mildest characterization of this amazing request is *misguided*" or not may be safely left with our membership. This much is certain, that whenever any one comes with a letter of introduction from this office, he will have first given assurances that his own establishment will reciprocate courtesies extended.

WHAT IS THOUGHT OF THE WORK OF OUR COMMITTEE ON INDUSTRIAL EDUCATION.

BY THE SECRETARY.

It will interest our members to know what men prominent in educational circles think of the disinterested and patient work of the Chairman of our Committee on Industrial Education. (Mr. Kreuzpointner has been chairman of, and in fact the whole committee, since its authorization and appointment at the Philadelphia Convention, May 23, 1907.)

OFFICE OF
JAS. B. DAVIDSON
COUNTY SUPERINTENDENT OF SCHOOLS
MARIN CO., CALIFORNIA.

SAN RAFAEL, CAL., October 28, 1912.

Mr. P. Kreutzpointner, Chairman,
Committee on Industrial Education.
American Foundrymen's Association,
Altoona, Pa.

DEAR SIR:

I wish to thank you for the bulletins and magazines you so kindly sent me and to assure you that I have read your articles with interest and profit. *You and your association are doing a splendid work.* There is no feature of government more important, so far as government can expend its power at present, than the education of the young for a life of usefulness. Every boy and girl should, must, be so educated that he can step out of school into some department of useful labor without any intermediate period of waiting for what may turn up. This waiting period is the time when boys and girls commit themselves to lives of uselessness, vice and crime. I know of no service to society a government can render, except elimination of the unfit by preventing their multiplication, which would bring so much happiness and blessing to the people as would the enforcement of such a system as you recommend; the teaching of trades and occupations to children from the seventh grade up. I have got new thoughts from your articles and a new insight into the needs of the children of this age and the relation of the public school to real life.

(Signed) J. B. DAVIDSON,
Superintendent.

DEPARTMENT OF PUBLIC INSTRUCTION.
SUPERINTENDENT'S OFFICE.

BUFFALO, October 3, 1912

Mr. Paul Kreuzpointner.
1400 Third Avenue, Altoona, Pa.

DEAR SIR:

Permit me to express my appreciation of your interest in our schools and especially of your letter to the Mayor. It is always easy to find fault with public officials and it affords a grateful change to find that a man abundantly able to distinguish the chaff from the wheat has found it possible to say some good words about our efforts in Buffalo to improve the character of the schools.

Very truly yours,

(Signed) HENRY P. EMERSON,
Superintendent.

TECHNICAL HIGH SCHOOL
A. S. HURRELL, PRINCIPAL.

BUFFALO, October 14, 1912.

Mr. Paul Kreuzpointner, Chairman,
Committee on Industrial Education,
American Foundrymen's Association,
Altoona, Pa.

MY DEAR MR. KREUZPOINTNER:—

I want to thank you and assure you of my sincere appreciation of your kindness in sending us the reports of the Foundrymen's Association and the set of P.R.R. specifications. I can assure you that these are a most welcome and valuable addition to our science department, and that you have gained for yourself through your kindness in this matter the gratitude and friendship of teachers and students of the Tech. I recall your visit with pleasure and profit, and I am hoping that we may have you with us again.

Cordially yours,

(Signed) A. S. HURRELL,
Principal.

FIRE PROTECTION FOR THE FOUNDRY.

AN INVESTIGATION BY THE NEW ENGLAND FOUNDRYMEN'S ASSOCIATION.

We have been so accustomed to watch the little items in our foundries, the production end thereby becoming highly systematized, that the big things settled by the higher officials in the office have escaped the attention they should have received. Thus, the works superintendent may slave to cut off another tenth of a cent a pound on the cost of his castings, while the sales organization, to meet competition—as they may think it—calmly lops off half a cent a pound on a bid. Similarly in the matter of the overhead charges, we have been accustomed to get bills for insurance without digging into the why and wherefore, considering them necessary evils. It would seem time, therefore, to insist upon a better development of the commercial end of our foundries, so that the big leaks that are in existence to-day in most places may be stopped up. Attention was called recently in your secretary's report to the Association at the Buffalo Convention, to the general lack of information on the average prices received for castings of various classes, and yet this is a vital element in the accounting of an establishment. The insurance of patterns, which is arbitrarily dealt with by the insurance interests, was the subject of considerable effort on the part of our committee, headed by Mr. Frederick Conlin, who with your secretary arranged a carefully thought out system of records, with classification of patterns, annual depreciation, etc., with the idea of receiving actual value in case of fire loss. After taking it up with the National Board of Fire Underwriters, and seeing divers big officials, the whole thing was calmly ignored by them, and it ended there.

We have in this country grown so used to the mediæval robber baron tactics of great lines of interest that until very recent times the task of curbing them has seemed hopeless. It is with pleasure, therefore, that we see the general subject of

fire protection taken up by an able committee of the New England Foundrymen's Assciation, consisting of Messrs. B. M. Shaw, chairman, and George P. Aborn and Henry A. Carpenter, whose report the association in question has kindly allowed us to embody in our Transactions.

The report itself is highly interesting and timely reading, and we will all agree with its conclusions. Let us hope that this disinterested work may be the precursor of further investigations to cover the entire country, and to formulate a more equitable business arrangement between foundry and insurance interests. There is still, however, a larger question involved. In almost the opening paragraphs of the report there is the statement: "Insurance men are, of course, the final authority on such hazards, etc." Here is room for public action. From the experience most of us have had with insurance companies, there has been developed the feeling that these corporations are there to serve the public—with proper compensation for such service. The public is hardly satisfied to have one party only to an agreement be the final authority. Our insurance departments have been so occupied in watching the internal affairs of the companies that they have not given attention to constructive legislative advice to the State authorities which would give the individual citizen or corporation a chance for equitable adjustment of premiums and losses. The matter of pattern insurance is a good example. To put a flat ten per cent maximum of the total insurance as allowable on patterns in a foundry means that either the insurance companies do not know how or will not give the attention to this matter that it deserves; or they simply hold the foundrymen to be malefactors when it comes to fire adjustment, and thus protect themselves against too heavy a graft. May we hope that the New England Foundrymen's Association will follow up the matter and ask other local and national organizations help push the work along and so systematize methods of appraisal and records that the talent employed by the insurance companies will be able to cope with the situation, and a fair annual charge for insurance in the "overhead" result.

FIRE PROTECTION COMMITTEE REPORT.

To the New England Foundrymen's Association:

Introduction.—Your committee sought information in regard to the fire hazard in foundry properties from all members of our association and also from some New England foundries without the organization. Replies were received from 133, but in 15 cases there was no foundry in operation, thus reducing the number of cases to be studied to 118.

In making a study of the replies the committee sought to arrange the material into various broad classes. This subdivision enabled us to draw a comparison between the general types of construction which would have been impossible had the classification been made too exacting.

In addition to considering the fire hazard in foundry properties from the standpoint of construction your committee was also able to use the reported insurance rates as a basis for such a survey. Insurance men are, of course, the final authority on such hazards and it was found that their rates reflected not only the hazard due to construction, but also the smaller hazards. Although it has been impossible to arrive at any exact and definite, and at the same time practical, means of enormously reducing the fire hazard in foundries, we feel that a study of this report will be illuminating to foundrymen and will enable them to use their judgment in making those changes which the general findings would seem to prompt. The report on the whole is meant to be suggestive rather than anything else, and with this in mind we would invite your attention to the following:

Construction.—In 50 cases the construction of the foundry was brick and concrete or brick and concrete in different portions. In 22 cases construction was a combination of wood and brick. Forty-six of the 118 foundries (39 per cent of total) were built of wood. These are mainly the smaller plants, and some of them carried no insurance.

Roofs and Roof Trusses.—The roof coverings of the different foundries were made up of a great variety of materials, and in

many cases different portions of the buildings were covered with different kinds of roofing material. In some cases as many as three different materials were used for a single plant. In order to determine just how the different materials were distributed the committee has taken the cases where subdivision was made and credited each material with a unit, just as in those cases where only one material was used. On this basis the totals will be somewhat greater than the number of plants studied. As the cases of duplication, however, involve usually the largest plants this method is believed to represent closely the general conditions.

In general the roof construction is fairly good, but in spite of this the greatest care should be taken to guard against sparks from the cupola. This is an ever present danger and a hood over the stack will do much to keep sparks from flying to the roofs of buildings or on the flasks. If possible the parts adjacent to the cupola should be absolutely fireproof, and it should be someone's duty after the cupola is dropped to go over the foundry to see that no tiny fire has started.

The tar and gravel roof is the most numerous of all, being found on 75 foundries out of 118. Slate roofs appeared in 39 cases; iron or tin clad in 17 cases. The remaining 18 cases included asbestos, plank, paroid paper, reinforced concrete and two cases of shingled roofs, both of these being on wooden buildings.

The roof trusses were in all cases either wood or steel, except that in a few cases the two materials were both used in a single foundry. Wood trusses predominate with a total of 91 against 30 for steel trusses, and six cases where the information was lacking.

Outside Exposure—Wooden Leantos and Flasks.—In 65 cases wooden leantos, either against the foundry building or close to it, make an external hazard which naturally results in raising the insurance rate. Forty-eight foundries report no leantos of this character, and in five cases no information was given.

The external risk produced by wooden flasks is considerable in many cases, and as a general proposition these flasks have no protection which would reduce the hazard. Eighty-seven foundries reported flasks piled in the open yard without protection; in only five of these cases were they at a distance from the foundry. Eight foundries reported flasks in the yard with protection of some sort, which would tend to minimize the danger to the foundry

itself in case these flasks should be set afire, either from smouldering sparks from a previous heat or any other way. In 23 cases there were either no flasks stored outside or no information given.

One of the cheapest and best methods to protect against these external hazards is to have a small hose house with the hose already attached to the hydrant. This enables the workmen to quickly get water to any blaze that starts outside the foundry in that immediate vicinity. If there are external hazards at points somewhat remote from the hose house, it is well to have a small carriage in the house so that one man can get a line of hose quickly to the hydrant nearest the blaze. In this house can also be stored the various bits of extra fire-fighting equipment needed, including extra hose, axes, spanners, play-pipe, bars, etc.

In planning for any such equipment as outlined above it is essential to remember that all the fire-fighting equipment in the world is of no value unless it is always in good working order and in the same place so that it can serve its purpose the second it is needed, for fire waits for no man. To secure this end, several of the larger foundries report that they use inspection slips which have to be filled out periodically by the man in charge of the fire-fighting equipment. These slips not only state the apparatus to be inspected, but also mention the exact location, so that there may be no time lost in hunting for a piece of hose, an axe or some other bit of apparatus which is not where it should be.

All of the information given above deals with the fire hazard in the various properties studied. We should expect naturally to find this hazard reflected in the insurance rates, to be dealt with at a later point, and this, in fact, is what occurs. Another item, which has a still stronger bearing upon the insurance rates, is the character of the protection afforded to each foundry by its own facilities and appliances for fighting fire, as well as by the proximity and adequacy of public fire departments and water supplies.

Public Fire Department.—In all but three cases the public department is available for coping with a fire. In a number of these cases, however, the department is at a distance and in some cases it consists of a volunteer department instead of a regular paid force. Quite a number of cases show village departments and in a few instances reliance to a certain extent is placed upon hand engines, there being no power operated engines or steamers

available except at a considerable distance. All of these items are, of course, strongly in evidence in the ultimate insurance rates charged those foundries.

The water supply for these various properties consists usually in city pressure or village pressure, as the case may be. This has been studied in the same way as the construction, and hence shows an excess number of plants under the same basis as before. City pressure is the reliance in 84 cases out of 118. In 20 cases hydrants on the property and belonging to the plant, furnish water, but in many of these the pressure is simply that from the city mains, although in some cases it is from an elevated tank or a reservoir with gravity pressure. Gravity tanks are mentioned as a source of supply in 17 cases, 13 of which are among the 32 plants protected by automatic sprinklers. Fire pumps, some of them automatic, are used in 16 different plants, many of which use them simply as an adjunct to other sources of water supply. In only one case was a pressure tank mentioned, that being the only supply to one of the automatic sprinkler systems.

Automatic Fire Protection.—Thirty-two of the plants reported automatic sprinklers and 13 of this number reported automatic alarms as well. Of the 32 sprinklered foundries, two reported water supply from three independent sources, 15 reported from dual sources and 15 from a single source, although it is possible that in some of these latter cases connection may have been made to two different city mains on different streets. A general study of the conditions has shown, as will be noted later, that the plants using automatic sprinklers have very much lower insurance rates than any of the others, the difference being a large percentage of the rate required of those plants which are not thus protected. It might be noted here that the sprinklers are placed in the most modern and largest plants; 22 out of 32, for instance, being in the plants which are built of brick, or brick and concrete, and only ten of them in the plants of less robust construction.

Insurance Rates.—In a great many cases it was difficult to obtain from the replies a satisfactory basis for analysis of insurance rates. Either the rate was given for a blanket policy covering a complete range of buildings of which the foundry was only one, or the rate was given without any valuation or amount of insurance carried, in which case it could not be averaged in with

the other figures because of variations in sizes of plants, etc. There were, however, 73 cases which form the basis for the figures which follow, these ranging all the way from one plant which carried only \$500 of insurance to two plants which carried \$650,000 each. The rates varied all the way from 4½ cent, per \$100 of insurance on one plant which was thoroughly protected by automatic sprinklers, automatic alarm, and two or three sources of water supply, to \$4.28 per \$100 of insurance (a rate 100 times as high) upon a small plant constructed of wood and without fire-fighting facilities. Nearly all of the wooden buildings carried a rate in the neighborhood of 2 per cent; whereas, the highest net rate in the sprinklered plants was 25 cents per \$100, or one-quarter of one per cent.

Taking up first the plants protected by automatic sprinklers, in 13 cases figures were given which we can use. These showed a total insurance carried of \$3,019,750, on which the net premiums, after deducting the regular annual return premiums of the Factory Mutuals, amounted to \$3,172. This makes the average rate 10½ cents per \$100 of insurance carried.

The brick and concrete buildings not protected by sprinklers afforded 18 cases which can be used. The rates ran from 50 cents in one case of good construction and satisfactory fire-fighting arrangements, to \$2 per \$100 of insurance in another case where the hazard and fire-fighting ability were not so satisfactory. The total valuation of this group of buildings was \$322,389, as shown by insurance carried. The amount of premiums was \$3,116, thus showing an average rate of 96½ cents per \$100 of insurance.

The group of buildings in which brick and wood both entered into the construction gave us 12 cases which could be used, the rates varying from 98½ cents to \$2.85 per \$100 at risk. The total valuation figured out at \$356,750, upon which insurance premiums aggregated \$4,683, or an average of \$1.31¼ per \$100 insurance carried.

The wooden buildings without sprinkler protection furnished the remaining 30 cases, the rates varying from \$1 to \$4.28 per \$100 at risk. The total valuation was \$330,450. The insurance premiums amounted to \$6,187, thus making the average rate \$1.87¼ per \$100 insured.

The above figures offer food for a great deal of thought. In the first place, it will be noted that the total insurance carried on the 73 plants for which figures were available amounted to $4,029,339, on which the insurance premiums aggregated $17,158 per annum, or an average rate of 42½ cents. The very great effect of the large sprinklered plants in bringing down this average figure will be at once apparent. What should be called to mind right here, however, is the relation between valuations and insurance demands on the plants differing in construction and protection. For this purpose the above figures are shown in the table as follows:

Class.	Number.	Valuation.	Premiums.	Rate.
Brick and concrete.............	18	$322,389	$3,116	.96½
Brick and wood.................	12	356,750	4,683	1.31¼
Wooden buildings..............	30	330,450	6,187	1.87¼
Sprinklered.....................	13	3,019,750	3,172	.10½
	73	$4,029,339	$17,158	.42½

The third item shows 30 plants with a total valuation less than one-ninth that of the 13 sprinklered plants, and yet they are paying practically double the annual insurance premiums. In other words, they are paying 18 times as high a rate as are the better protected foundries. Even the foundries housed in concrete or brick buildings but not equipped with sprinklers show an immense difference in rate over those which are sprinklered. With a valuation between 1/9 and 1/10 that of the sprinklered plants, they are paying almost identically the same insurance premiums, the rate being more than nine times as high as in the sprinklered foundries.

Recommendations.—The Committee cannot recommend too strongly that all members take all possible means to avoid danger from fire. By this we mean that particular care should be taken to keep all rubbish cleaned up; to see that all flasks before being stored are entirely free from smouldering particles; to see that all possibility of the spreading of a fire from one portion of the plant to another be done away with. In all cases where flasks are stored against the outside of the building or close to it, or

where wooden leantos are against the building, the windows back of and above these hazards should receive proper protection. If it is not feasible to fit metal sash with wired glass panes operating in metal casings, either a sheet iron screen should separate the hazard from the property or whenever possible the wooden hazards should be removed far enough from the building to do away with danger of spreading fire.

Fire pails located at several convenient points should be always full of water and never used for any other purpose. The use of portable chemical extinguishers, of some one of the several types recommended by the underwriters, is heartily approved.

In all cases where it is not financially possible to install automatic sprinklers and automatic alarms, even with the insurance saving which follows this installation, standpipes with hose already connected should be located at points where they will be readily accessible, even with a fire raging in the building. Where feasible it is suggested that a pump taking suction from a river or pond is a good source for standpipes when a tank would be too expensive. Valves for these pipes should be capable of operation from the outside of the building or from a fully protected location inside. It is frequently feasible to fit a small valve room totally incombustible in itself and in its contents, which can be entered from the outside of the building, and which would contain in a frost-proof compartment the necessary valves, hose, etc., to fight even a heavy fire. Where sprinklers are used on the dry-pipe system these connections could well be made in the dry-pipe valve room, but it is very important that this room, whether used for the sprinkler system or for the hose system, should be accessible under any and all conditions which might arise.

Most small foundries have city water for a drinking supply. This can be very inexpensively converted into a fire-fighting auxiliary by merely making a few small hose connections for 1 in. pipe to which is attached from 50 to 200 feet of hose with a nozzle already connected. This hose should be coiled on a swinging rack. By thus utilizing the means at hand a serious fire may often be held in check until the fire department arrives, while small blazes can be entirely extinguished.

Conclusion.—The committee feels that if this study should have the result of inducing any of our members to improve the

conditions in their plant, either by reducing the fire hazard or by providing secure means for taking care of a fire when once it starts, its labors will be amply repaid. The mere question of insurance savings due to improved conditions from the fire standpoint is, we recognize, quite subsidiary. The fact that a single crippling fire might mean loss of business for months, carrying with it the possible loss of established trade, and seriously hampering other departments of a large establishment, must always far overshadow any question of insurance premiums as such. The fat, however, that both ends may be served at the same time and by the same means, makes it extremely important that all members should use, to as large an extent as practicable, all the means at hand for cutting down the risk of destructive fire and at the same time cutting down their insurance payments.

Statistics.—A somewhat detailed tabulation of construction and other features as brought out in preceding paragraphs, follows on a separate sheet. The figures are grouped under four different headings, of which the first represents buildings of brick, or brick and concrete; the second represents buildings in which wood and brick both entered; the third represents buildings of wood; the fourth represents buildings protected by automatic sprinklers and includes all three forms of construction.

Respectfully submitted,

B. M. Shaw, *Chairman*,
George P. Aborn,
Henry A. Carpenter,
Committee.

TYPE OF BUILDINGS.

Roofing.	Brick and Wood.	Brick and Concrete.	Wood.	Sprinklered.	Totals.
Roofing.					
Tar and gravel	15	14	23	23	75
Slate	11	9	6	13	39
Iron or tin-clad	2	4	7	4	17
Asbestos	2	..	2	1	5
Reinforced concrete	3	1	..	..	4
Special papers	..	..	5	1	6
Plank	..	..	..	1	1
Shingles	..	..	2	..	2
Roof Trusses.					
Wood	20	17	34	20	91
Steel	9	5	..	16	30
Leantos.					
Wood	12	11	27	15	65
None	16	6	11	15	48
Wooden Flasks.					
Protected	..	1	2	5	8
Unprotected	19	14	32	22	87
None or no information	9	3	6	5	23
Water Supply.					
City or village mains	17	12	28	27	84
Own hydrants	8	4	8	..	20
Gravity tanks	2	1	1	13	17
Fire pumps	1	3	3	9	16
Pressure tanks	..	..	..	1	1

AMERICAN FOUNDRYMEN'S ASSOCIATION.

EXPERIMENTAL INVESTIGATION OF THE CUPOLA MELTING PROCESS.

By Frederick Hueser, Griesheim, Germany.

(Reviewed by the Secretary. From *Stahl und Eisen*, January 30, 1913.)

A rather elaborate investigation of the metallurgical and thermic conditions incident to the cupola melting process was conducted by Mr. Hueser at the foundry of A. Borsig, in Tegel, Berlin. An old Krigar cupola was used, a sketch of which, with dimensions in millimeters, is given in Fig. 1. The cupola was provided with two tuyeres only, one in front a little over 2¾ by 7½ in. in cross-section, and the other directly opposite in the back, but somewhat lower, 5¼ by 20 in. the total area of both tuyeres being one-tenth that of the cupola cross-section. (The cupola diameter is almost 34 in.) Blast was furnished by a positive blower giving a fairly steady volume, the pressure varying somewhat, depending upon the condition of the tuyeres and charges—that is, rising toward the latter part of the melt. It began with 14 in. water, rose to 24 in. and remained between that figure and 28 in. to the end. The tuyere arrangement given is interesting from the standpoint of American practice, and is probably not duplicated anywhere in this country. There would be indicated the correctness of the assertion that it is possible to melt iron in an old brick-lined boiler with a few holes punched in to serve for tuyeres. The amount of air blown in is given as sufficient to melt 5.5 tons per hour, which is excessive for this size cupola, from our point of view. Hence, probably the greater hardness of castings in European practice when compared with the American.

Gas samples were taken from six points in the cupola, as indicated in the illustration. The lowest one *a* is just below the bottom of the higher front tuyere, the next one in the lower point of the melting zone, the next in the upper portion of the melting zone, then three more further up, the last one being just below the charging door. The method of taking the gases is shown in Fig. 2. The perforation of the cupola by the pipe *a* is made gas

tight by means of a stuffing box through which the gas tube is run. The replaceable end of this is protected by an overhang of brick at the point indicated, so that the descending iron and slag might not damage it. Special precautions had to be taken in the case of the lower points, as the openings would "bung up" continually.

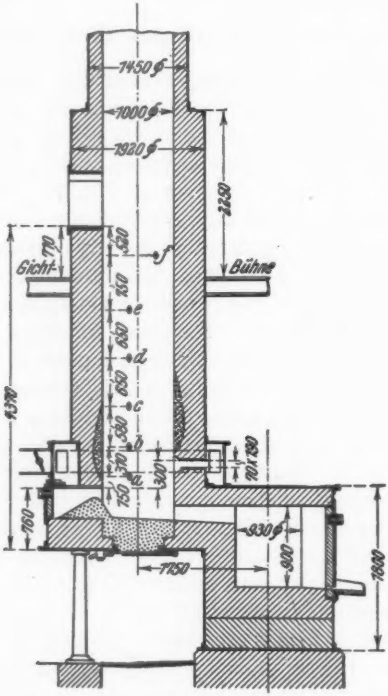


Fig. 1.

The difference between these tests and the ones made by the United States Government, presented at the Buffalo Convention, and to be published shortly in these Transactions, is that in the latter no iron was melted and hence the arrangement for sample taking of gases and temperatures was not complicated. Moreover, the gas tubes, being water-cooled, could be left in the

several positions in the interior of the cupola and hence get satisfactory gas samples, which was not the case in all the German tests. The American results are therefore much better for points below an actual melting of iron, few tests having been made above. The German tests here given have the advantage of actual melting operations though also all the consequent difficulties.

The composition of the gases taken from the lowest perforation is not given, as the results were not reliable enough. For the next point, however, they could be taken fairly well and ran as follows:

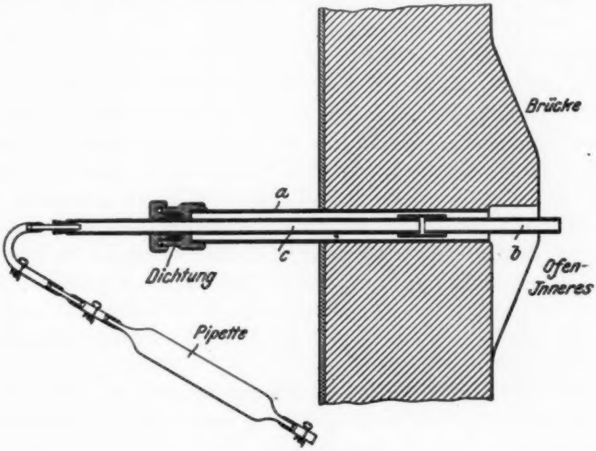


FIG. 2.

Eight tests made from three minutes after blast was put on to two hours after. CO^2 varied from 16.9 to 19.5, CO from 0.1 to 2.9, Oxygen from 0.4 to 2.7, Nitrogen from 76.9 to 80.7. As this was taken right from the rim of the melting zone, the oxygen naturally is marked, but there is also shown an excellent combustion, judging from the high CO^2 and comparatively low CO.

The next point higher up (*c* in Fig. 1), or the upper portion of the melting zone, gave the following: Twelve tests made from three minutes after putting on blast to three hours after. CO^2 varied from 9.5 to 18.0, CO from 3.5 to 17.4, and Oxygen from 0.2 to 1.6. This shows a bigger variation in the CO, and still a

lot of uncombined oxygen. The point *e* of Fig. 1 gave the following results: CO^2 from 7.6 to 16.8, CO from 5.2 to 19.4, and Oxygen from 0.3 to 1.7. In the last results it will be noticed that the CO is rising very much, showing that the CO^2 is taking up carbon from the incandescent fuel, wasting it and also reducing the temperature. At the point *e* of Fig. 1 the following results were had: CO^2 from 6.7 to 17.9, CO from 3.4 to 15.4, and Oxygen from 0.3 to 1.4. Finally at the upper point just below the charging door, and unaffected by the air entering this, the results of the gas samples taken are as follows: CO^2 from the rim of the cupola ran 8.8 to 15.9 and from the center 3.4 to 16.7, the CO at the rim from 6.7 to 14.9, and 6.3 to 18.3 from the center. The oxygen at the rim from nothing to 1.6, and 0.4 to 1.6 at the center.

These figures simply show that after the gases pass from the region of incandescent fuel there is little change in them. There is also indicated the importance of absorbing as much of the heat of the gases above the melting zone by the metal charges as possible, to minimize the chances of bringing to incandescence the fuel charges higher up where CO can be formed, as was evidently the case in this test. Only small charges will assist in this, the ideal conditions being a uniform mixture of metal and fuel throughout the run, so that there may be no fluctuation of the melting zone whatever.

Sulphur determinations were made in the gases of the cupola on four occasions, the average amount being 0.978 grammes per cubic meter. The temperatures were taken with a Le Chatelier pyrometer up to the fusing point of platinum, and after that with the Wanner pyrometer. At the point *a* of Fig. 1, the results were so unsatisfactory that they could not be used. At *b* the highest temperature measured was 3150° F. In all cases the temperatures began rather higher and dropped down quickly at first and then quite slowly to the end. This is ascribed to the changing coke bed, but is more likely attibutable to the formation of the high percentages of CO with consequent temperature reductions.

The average temperature records for the several points observed are as given herewith: For *b*, unreliable; for *c*, 2650° F.; for *d*, 2200° F.; for *e*, 1900° F.; for *f*, 1750° F. These temperatures indicate that melting is possible at a considerable dis-

tance above the point where scoring of the cupola is observed. It incidentally emphasizes the importance of free oxygen as a dangerous element to be reckoned with. It is unfortunate that no attempts were made to get gas determinations and temperatures from the interior of the cupola during the melt. These would have given additional proof of the upward tendency of the blast and the formation of a bed cone of fuel in the center as mentioned in the article.

One row of tuyeres made wide but not high is recommended as best calculated to hold the melting zone at the proper place of maximum effect. A rather interesting discussion anent the changing of the blast volume during the melt and consequent melting troubles is given. The latter are charged to the bunging up of the tuyeres, whereas a careful study would connect them with the change of position of the melting zone and consequent improper position of the metal charges. Nevertheless, an interesting point is given, namely, "if the bed is too high and an excess of blast is used, the temperature may become so high that particles of iron are oxidized and carried along, giving the gases rising from the cupola a red-brown color."

Mention is made of Mr. Thomas D. West's claim that when the cupola is run hot there is less loss of iron, silicon and manganese than when running cold. Prof. Osann corroborates this with an example of melting for the converter, where with too little coke a manganese percentage was reduced from 2 per cent to 0.80 per cent, whereas with an excess of coke the loss of manganese was zero, the blast volume being the same in each case. A test of this kind was made in the cupola in question at the Borsig works, only that the bed coke remained the same and the blast volume was changed. The result was that when the blast volume was heavily increased double the amount of iron was burned, so that the slag contained 31.2 per cent iron. Instructions are given regarding the best manner of changing the blast volume and maintaining the same pressure, in case smaller or larger quantities of molten iron are required. This again shows the radical difference between German and American melting practice. Over here it is known that a variation in blast volume during the melt is very bad practice, as it changes the position of the melting zone with respect to the bed, and cold iron is certain to result

together with other troubles when full blast is put on again. We simply shut the cupola off for a few minutes, draining out the molten iron, and when iron is wanted again, put on the normal blast.

The mixture used in these tests was of the following analysis: Total Carbon 3.30, Silicon 2.52, Manganese 0.72, Phosphorus 0.68, Sulphur 0.059. During the melting a series of eighteen samples were taken for analysis, and these show the following: Total carbon from beginning to end remains practically as it was. Silicon begins with an average of about 1.90 and runs up to an average of about 2.35 at the end, showing an exceptionally heavy oxidation in the early part of the heat. Manganese remains constant at about 0.60. Phosphorus is practically unchanged, and sulphur with the exception of the first tests, where it rose to about 0.15, runs averaging 0.11, or about double the original amount.

A criticism of the analyses from the American standpoint would indicate an extreme forcing of the cupola. German practice is so tied to small cupolas (which in itself is a good policy) that to get sufficient metal without having too many cupolas about the place the tendency will naturally be to force them unduly. In this country, where soft iron is essential for the machine shop, any undue forcing of the cupola soon reveals itself in hard (oxidized) iron.

An elaborate calculation of the heat balance concludes the article. It is not gone into here, as only the differences in melting practice are of special interest to us.

AMERICAN FOUNDRYMEN'S ASSOCIATION.

INDENTURE FOR MACHINERY MOLDERS' APPRENTICE.

THIS AGREEMENT, made and entered into this ________________ day of ________________ A. D. 19_____,

between ________________________________, doing business under the firm name of ________________________________ (or a Corporation organized under the Laws of the State of ________________), of the city of ________________, county of ________________, State of ________________ part_____ of the first part, and ________________________, a minor, and ________________________ his father (or his mother or guardian), parties of the second part.

THIS INDENTURE, WITNESSETH, that the said party of the first part, agrees to take ________________ ________________________, a minor, the first named party of the second part, into __________ employ or service, for the period of four years from the date hereof, for the purpose of teaching the trade of iron molder to the said ________________ ________________________, minor, as carried on in ________________ works, in the manner hereinafter specified.

And that the said______________________________,
minor, the first named party of the second part, covenants and agrees that he will faithfully, honestly and industriously work and serve for the said period in such capacity as the foreman may from time to time direct, and that he will obey all rules and regulations in vogue in said works, and will not absent himself from the service of the party of the first part without leave, unless in case of sickness, and further covenants and agrees to abstain from the use of intoxicating liquors during said term of apprenticeship.

The said______________________________, minor, further agrees and covenants that he will faithfully perform the work assigned to him, which is as follows, but may be deviated from as long as it does not impair the apprentice's opportunity to learn the trade thoroughly.

Nine months of the first year shall be devoted to making cores and taking care of core boxes, patterns, etc., and three months in taking care of the cupola and ladles. Second year at light molding of various kinds and in assisting in the care of patterns and helping molders, as occasion may require. Third year to be advanced to a heavier and more difficult class of work as fast as he may prove himself capable. Fourth year to be spent on the best class of work in the shop, whether made in dry or green sand.

The said______________________________, minor, agrees to make up all time lost by him, whether by sickness or absence, each year before he commences on the following year.

The said party of the first part covenants and agrees to teach, or cause said apprentice to be taught or instructed in the trade, where he is apprenticed to learn.

The said party of the first part further agrees to pay unto the said______________________________, minor, for services rendered while learning his trade, for the first year,__________ dollars per week; for the second year,______________dollars per week; for the third year,______________dollars per week;

and for the fourth year, ________________ dollars per week, and an additional bonus of ten dollars at the end of the first year, twenty dollars at the end of the second year; thirty dollars at the end of the third year, and forty dollars at the end of the fourth year of his apprenticeship, it being understood that the paying of these bonuses is optional on the part of the party of the first part, and shall only be paid when the first party is satisfied that the apprentice has faithfully performed all requirements.

If the said ________________________________, minor, shall work an additional year on loam work, the party of the first part shall pay unto him the sum of ________________ dollars per week, and a bonus of fifty dollars at the end of the said additional year, on the conditions named above for the previous years.

The said ________________________________, father (or mother or guardian) of said minor, covenants and agrees that the ________________________________, minor, shall faithfully perform and observe all of the covenants and stipulations which he has herein covenanted and agreed to.

IN WITNESS WHEREOF, the said parties have hereunto affixed their hands and seals the day and year first above written.

________________________________ (Seal)

________________________________ (Seal)

________________________________ (Seal)

INDENTURE FOR AGRICULTURAL AND STOVE MOLDERS' APPRENTICE.

THIS AGREEMENT, made and entered into this ________ day of ________ A. D. 19____, between ________, doing business under the firm name of ________ (or a Corporation organized under the Laws of the State of ________), of the city of ________, county of ________, State of ________ part____ of the first part, and ________, a minor, and ________ his father (or his mother or guardian), parties of the second part.

THIS INDENTURE, WITNESSETH, that the said party of the first part, agrees to take ________ ________, a minor, the first named party of the second part, into ________ employ or service, for the period of three years from the date hereof, for the purpose of teaching the trade of iron molder to the said ________ ________, minor, as carried on in ________ works, in the manner hereinafter specified.

And that the said__________________________________,
minor, the first named party of the second part, covenants and agrees that he will faithfully, honestly and industriously work and serve for the said period in such capacity as the foreman may from time to time direct, and that he will obey all rules and regulations in vogue in said works, and will not absent himself from the service of the party of the first part without leave, unless in case of sickness, and further covenants and agrees to abstain from the use of intoxicating liquors during said term of apprenticeship.

The said__________________________________, minor, further agrees and covenants that he will faithfully perform the work assigned to him, which is as follows, but may be deviated from as long as it does not impair the apprentice's opportunity to learn the trade thoroughly.

First six months, day work, to be spent in taking care of patterns and core boxes. Second six months in becoming acquainted with the care of cupolas, ladles and flasks, so as to become familiar with their use before starting to mold. Second year to start at the more simple class of work, and the more difficult pieces of work to be given him as he proves himself competent. Third year to be spent on the most difficult classes of work.

The said__________________________________, minor, agrees to make up all time lost by him, whether by sickness or absence, each year before he commences on the following year.

The said party of the first part covenants and agrees to teach, or cause said apprentice to be taught or instructed in the trade, where he is apprenticed to learn.

The said party of the first part further agrees to pay unto the

said__________________________________, minor, for services

rendered while learning his trade, for the first year,____________

dollars per week, day work; second year, board prices less______

per cent. piece work; third year, board prices less_____per cent.

piece work; and a bonus of $10 for extra efficiency at the end of the second year, and $20 at the end of the apprenticeship; it being understood that the paying of these bonuses is optional on the part of the party of the first part, and shall only be paid when the first party is satisfied that the apprentice has faithfully performed all requirements.

The said ______________________________, father (or mother or guardian) of said minor, covenants and agrees that the ______________________________, minor, shall faithfully perform and observe all of the covenants and stipulations which he has herein covenanted and agreed to.

IN WITNESS WHEREOF, the said parties have hereunto affixed their hands and seals the day and year first above written.

______________________________(Seal)

______________________________(Seal)

______________________________(Seal)

INDENTURE FOR BENCH AND BRASS MOLDERS' APPRENTICE.

THIS AGREEMENT, made and entered into this ________________ day of ________________ A. D. 19____, between ________________________________, doing business under the firm name of ________________________________. (or a Corporation organized under the Laws of the State of ____________________), of the city of ____________________, county of ____________________, State of ____________________ part____ of the first part, and ____________________________, a minor, and ____________________________ his father (or his mother or guardian), parties of the second part.

THIS INDENTURE, WITNESSETH, that the said party of the first part, agrees to take ____________________ ________________________, a minor, the first named party of the second part, into ____________ employ or service, for the period of two years from the date hereof, for the purpose of teaching the trade of molder to the said ______________ ______________________________, minor, as carried on in ________________ works, in the manner hereinafter specified.

And that the said ________________________________,
minor, the first named party of the second part, covenants and agrees that he will faithfully, honestly and industriously work and serve for the said period in such capacity as the foreman may from time to time direct, and that he will obey all rules and regulations in vogue in said works, and will not absent himself from the service of the party of the first part without leave, unless in case of sickness, and further covenants and agrees to abstain from the use of intoxicating liquors during said term of apprenticeship.

The said ________________________________, minor, further agrees and covenants that he will faithfully perform the work assigned to him, which is as follows, but may be deviated from as long as it does not impair the apprentice's opportunity to learn the trade thoroughly.

First six months to be spent in taking care of cupolas and ladles, and working at the core bench, so as to become familiar with his surroundings. Balance of his apprenticeship to be devoted to molding entirely, and to be given change of work, and a better class of it as fast as he becomes proficient.

The said ________________________________, minor, agrees to make up all time lost by him, whether by sickness or absence, each year before he commences on the following year.

The said party of the first part covenants and agrees to teach, or cause said apprentice to be taught or instructed in the trade, where he is apprenticed to learn.

The said party of the first part further agrees to pay unto the said ________________________________, minor, for services rendered while learning his trade, for the first year, ____________ dollars per week; for the second year, ________________ dollars per week if day work prevails. Where piece work is the rule ________________ dollars per week for the first six months;

board prices less_____per cent. for the second six months; board prices less_____per cent. for the balance of the term, and a bonus of ten dollars at the end of the first year and twenty dollars at the end of the second year shall be added to the above; it being understood that the paying of these bonuses is optional on the part of the party of the first part, and shall only be paid when the first party is satisfied that the apprentice has faithfully performed all requirements.

The said ____________________________________, father (or mother or guardian) of said minor, covenants and agrees that the ____________________________________, minor, shall faithfully perform and observe all of the covenants and stipulations which he has herein covenanted and agreed to.

IN WITNESS WHEREOF, the said parties have hereunto affixed their hands and seals the day and year first above written.

____________________________________(Seal)

____________________________________(Seal)

____________________________________(Seal)

AMERICAN FOUNDRYMEN'S ASSOCIATION

THE PRODUCTION OF MALLEABLE CASTINGS.

BY DR. RICHARD MOLDENKE, WATCHUNG, N. J.

(An address before the *Connecticut Valley Section* of the American Chemical Society, Hartford, Conn., January 4, 1913.)

Mr. Chairman and Gentlemen:—The malleable casting is a very peculiar one. It has a place among iron products that is particularly unique. It is the only form of cast iron that we know of in which, by the application of heat treatment, there is an absolute change from bad to good, or from a useless condition to a magnificently useful one. The malleable casting as it was known in the early part of the eighteenth century is the same casting as it is to-day, we have only fixed the underlying principles of the process, and know more about why things are done now than they did then. All attempts to change the making of malleable castings have failed; but we are learning how to make it more uniform.

The malleable casting is a distinct product of this country. Whereas, I presume, the entire production of malleable castings in the civilized world outside of the United States and Canada, may be placed at seventy-five thousand tons per annum, the capacity of this country is at least a million tons a year, and we probably make something like nine hundred thousand. This is a fairly large business when compared with the balance of the iron and steel industry, for the ordinary gray iron foundry output is about eight million tons a year. We are therefore dealing with something that has a very important place in the political economy of the country.

I have frequent requests from individuals and manufacturing concerns for information which will enable them to start in the malleable iron casting business. I advise them to keep out unless they really have the right market conditions. Otherwise it would prove a rather costly experience. The producing capacity of the country grows with the demand, and anyone

3

who goes into this business without knowing just what the demand is has got a very serious times ahead of him.

A further difference between the malleable casting industry and the ordinary grey iron is that the plant is at least four times as costly. Hence the "overhead" expense is to be reckoned with carefully. Moreover, the running capital must also be ample as the "turn over" of the material is far slower than in the case of gray iron castings.

Réaumur, the French chemist, described the first malleable iron that we know of in 1722; and that casting is to-day made in Germany, France and England as it was made then. There are two general classes of the malleable casting. The practice in America, and partly also in England now, is to make these castings with the so-called "black heart." If you fracture an American casting you will see that the interior is black, while the rim is white; while the European casting is entirely white. In other words, the carbon of the European casting has been almost entirely removed, whereas the carbon in the interior of the American casting is nearly all there. There has been a conversion of the combined form of carbon to the so-called "temper-carbon."

Seth Boyden, of Newark, N. J., was the earliest manufacturer of malleable castings in this country. It was probably introduced here from England and he experimented considerably and left us a record of his work. Seth Boyden simply had to repeat the work of those who went before him, but he tried to learn for himself why those castings were made in that way. Probably a very costly business; because no man could illuminate the subject even if he would.

The most striking characteristic of the malleable casting is the remarkable resistance to shock. If you could see right through the structure, you would find that it is nothing more than a network or an aggregation of crystals of steel with flakes of lampblack between them. In other words, if you analyze the annealed casting, you would find the total carbon, say 3.75; made up of perhaps 0.40 combined carbon and all the rest graphitic carbon. Of course, silicon, manganese, phosphorus and sulphur additional. The combined carbon is in the crystals of iron, making them a 0.40 carbon steel; the graphite is there mechanically mixed between the crystals.

In the original hard white casting the carbon is all in the combined form, in the annealing process this is changed from the combined to the uncombined, amorphous graphitic state. If the skin of such an annealed casting is taken away, the interior portion will be found to contain the full amount of carbon changed, not to crystallized graphite, which pulls apart easily, but to an amorphous form appearing under the microscope like lampblack. So that, when it comes to shock resistance, owing to the fact that the graphite is not crystallized in "malleable," you can batter it to pieces at one end and the other will remain perfect. In my early experience along this line I cut coupons from scrap couplers of all shapes and kinds; and have taken them from couplers that had been in service a long time and come back worn out. I did the same with steel couplers; and the results indicated that whereas the malleable coupler invariably—if the iron was a good, proper malleable casting to begin with,—showed up good metal, the steel coupler did not always do so. It seemed to me from these tests that in a long steel casting, subjected to the stresses of railroad service, the face would begin to open, the crystals going apart; while in the malleable they crush together, the amorphous graphite acting as a cushion. In steel, the opening up of the crystalline structure would go on long enough to eventually ruin the casting. The other explanation would be that these steel castings may not have been properly annealed; and that they had casting strains which reduced their strength. The malleable casting is a much better casting to use for railway service where extreme strength in tension is not essential.

A good malleable casting ought to stand about 45,000 pounds to the square inch. I have made them as high as 63,000 to the square inch, but would not recommend that for every-day work. When we go into high tensile strengths for "malleable" we begin to reduce the shock-resisting and twisting qualities. I think that the great mistake being made to-day by purchasers of malleable castings is that they ask too much tensile strength of the malleable casting. It would be far wiser for them to go to the steel casting at once, because in trying to get a very high strength they must sacrifice the qualities of ductility, softness, etc. The ordinary, normal malleable casting without steel additions in the mixture runs about 35,000 pounds to the square inch. When

we begin to add a little steel scrap it will run to 45,000, or even up to 51,000 lbs. per sq. in. I have made about 80,000 tests on a "malleable" and the monthly average of the test bars started with 35,000 pounds to the square inch when I began the work—the average of all of them when I finished up was about 51,000 pounds to the square inch.

In the malleable casting we deal with a material which has passed through a special heat treatment. It is hard to start with and when it is annealed it is soft. Hence we can safely use a square bar. This is broken in the middle for the transverse strength and pulled in the testing machine for tensile strength. We deal with an iron that contains about 0.65 silicon, and hence there is a very large interior shrinkage in the metal apart from the contraction of the casting itself. This averages a quarter inch to the foot. Furthermore the iron sets very quickly, and the consequence is that when you pour a long bar, thirteen to fifteen inches long, the metal touching the sand sets first, and you have a liquid interior for a short space of time. Next the gate cuts off with the interior of the bar still liquid, then this begins to set and it shrinks and pulls apart inside. The interior of a malleable casting, or of any casting, is therefore filled with a whole lot of planes of separation. When you put a piece into the testing machine you will invariably find that the fracture shows up the interior shrinkage; there is a little bad spot in the center. It will always break at the weakest of these spots. I have repeatedly taken bars which had broken very close to the grip, put them in the machine again, and if they would break at the end again I tried them the third time The first time the bar may be broke at 42,000; next at 48,000; and the third time at 54,000. It is simply a case of breaking first at the worst of these spots; then at a less bad one; and then the least bad one. The consequence is that the test bar is better square than round for the reason that in a square bar you get proportionally very much more sound material than in the round one. Hence for malleable castings you must never use a round test bar. If intricate castings are to be made the design should suit this tendency to heavy shrinkage. They should be made so that there are no sharp corners nor very sudden changes from small to large section, because in the large portion there will be found

a heavy shrinkage spot by the gate cutting off before feeding is complete.

To go into the structure of the casting itself:—The hard casting (before it is annealed) is of the same composition throughout. Analyze the interior or the skin and you will find the same composition. After the annealing it is different. In the annealing there is a change from the combined carbon to the amorphous "temper carbon," and also the removal of some carbon from the surface of the casting. In the European malleable castings the removal continues through, as these are always thin and small and are annealed at higher temperatures. On the other hand, with us the temperature is just high enough to permit this carbon conversion and no more. Plane off the skin and in it you find 0.20 carbon; plane the next sixteenth of an inch off and you find 0.65; another sixteenth off, 1.50; and in the center perhaps 3.25, or whatever the total carbon in the hard casting may have been. If you take a malleable wedge, put it in the fire, make red hot, plunge and quench it, you can file the very thin edge. If you go through this skin you strike 1.50 carbon. There you have tool steel which will not file away. Further back grinding through this hard portion, you get the interior softness again. If you try to straighten a malleable casting by making it red hot you are liable to produce this very thing. There is a chance for the reconversion of the amorphous graphite or "temper carbon" back into combined carbon again. An instance of this in point:—We had a rush order for a lot of guard plates, I think five-eighths of an inch thick—and they came out of the anneal badly bent. The best thing was to try to straighten them cold, there being no time to straighten them hot and put them back into the anneal again. These plates were in the blacksmith's fire and straightened. Every one of them came back from service with the heated part broken off. The portion which had been heated and hammered was steely and white, and the portion not heated was nice and black. Here was that change of the uncombined carbon to the combined. And this shows how sensitive the malleable casting is to heat treatment. Straightening should be done cold.

An excellent service test of the malleable casting is the placing of test lugs on castings, trying to make them about the same thickness as the casting, and are broken off to see if the fracture

indicates good material. Foundrymen do not like to leave them on for the inspection of their customers. From the standpoint of the customer they should be available. In important work, however, it is well to have these lugs in several locations so that they could be broken off afterwards in order to have assurance that the casting was properly annealed before it was sent out.

As far as pattern work is concerned there is very little to say more than that the malleable casting is naturally made very thin and ribbed, as a rule, because by reason of its strength it replaces a gray casting perhaps twice or three times as thick. The malleable casting, is essentially repetition work. I have often received in our works orders for 65,000 to 100,000 pieces of one kind. It is rather nice work because of requiring enormous quantities. Hence, the molding machine has a good place in the malleable shop, and it is beginning to get there. The permanent, that is the iron, mold will find in the malleable casting shop perhaps its best application. So far there has not been much done in this line yet, but it is bound to come.

There are very few castings made in the malleable business that are not cored out. The very use of a strong, light malleable casting to replace gray iron means core work. So that the core room is a very important department in the malleable shop.

We come to the processes. These are the crucible, cupola, Bessemer converter, air furnace, open hearth, and electric. The crucible process makes the finest malleable as it does the finest steel, with the exception of the electric furnace—a comparatively new development. It is expensive, however, and consequently you will find the crucible made casting only in Europe where the malleable casting is more expensive than the steel casting. To show the differences in practice between Europe and this country, I will mention that I had to do with the designing of one of the largest European malleable plants. They made American malleable castings in it up to two years ago in place of the European. Then they had to give up making the American malleable casting for the reason that in Europe they machine their malleable castings. The last thing to do with the American "black heart" malleable casting is to machine it. The skin is the strongest portion of the malleable casting. It does not follow that the interior is not good, because I have often, to satisfy myself, taken

a malleable casting, planed off all the decarbonized portions and tested the interior; and where I found that the casting itself would stand about 43,000 to 48,000 pounds to the square inch, the interior portion alone stood about 42,000 pounds to the square inch. So that this interior was still very much better than gray iron. In Europe they take their malleable casting, turn it and finish it; as they do nearly all their work, and as the interior shrinkage naturally bothered them they had to go back to the European decarbonization method to succeed.

Next we come to the cupola. The cupola casting is used principally for such castings as pipe-fittings, agricultural work, and those things that require only a little better strength than the gray casting of the same kind, but more malleability. Cupola malleable is a little cheaper than the air furnace or open hearth product. In all malleable melting processes, inasmuch as the iron is very low in silicon and consequently sets very quickly, it loses its life very easily; and especially if it has been oxidized at all it must be gotten into the mold fast. Consequently a gray iron molder must be shown how to pour malleable; a little twist of the wrist throws the iron into the mold; otherwise it may be short poured. In cupola melting there is always a very low coke ratio; Melting is done on a very high bed; perhaps higher than it ought to be, but it is necessary to get the iron very hot and as free from oxidization as possible.

The Bessemer process is used in Europe only. They blow their heats to where the silicon is down to the right point, stop the heat, dioxidize and pour. What the castings look like I cannot say, but with their long anneal, in which the metal is decarbonized, they should make serviceable castings.

The air furnace is the furnace principally used for the production of "malleable" in this country because it lends itself particularly well to this class of castings. The malleable air furnaces are constructed differently than are the air furnaces for gray iron work. For gray iron they have large cross sections and are comparatively short. For malleable very long furnaces are used, a long flame being desired to get the best result. The heat to melt, whether in the air furnace or the open hearth, does not come from the direct action of the flame so much as it does from the radiation of the interior brickwork. The idea in the air furnace and

in the open-hearth furnace is to get the brick work lining so hot that the radiation downward upon the charge does the actual melting, and does it fast. So that no matter how much firing you do, if you do not fire to get your brickwork to such intense heat that the radiation melts the charge properly you get unsatisfactory results. Ask the malleable iron man what his ratio of coal to iron melted is; if he melts about two pounds to three pounds of iron to the pound of coal, he thinks he is doing well. Sometimes I have seen a pound of coal used for melting every pound of iron, whereas it ought to be about four pounds of iron to the pound of coal when you run three heats in one day and average them all up. The first heat with the colder furnace is a little harder on the coal supply than the others. I have observed the operation of many malleable plants. The first thing in going over the air furnace equipment is to see how they are kept. Not unusually you will find that you can look through the brickwork into the interior, there being plenty of spaces where cold air is drawn in. If you figure that the radiation of the lining does the work you can see how important it is that every square inch of the interior of the furnace should do its work.

And take the firing. I have seen the men throw the coal all over the bed of fire and then take the slice bar and poke it up, whereas the right way to do is to pile the coal at the door, shut the door, allow this coal to coke slightly, and then carefully push it over the entire area. Then repeat the operation, and repeat periodically instead of having the fireman using his shovel and bar all the time. He might just as well rest a little between the periods. The firing is something that must be watched very carefully in the air furnace installation. By so doing a constant flow of gas is obtained from the coal. While in boiler practice we figure on 100 per cent air admitted over the theoretical amount necessary to burn coal, if we get more than 25 per cent excess free air in the malleable furnace we begin to get trouble. If that 25 per cent in excess can be allowed uniformly, we then get that magnificent incandescence in the furnace which does the melting properly. If, on the other hand, the firing is done by fits and starts the melting is unduly prolonged. One cannot be too particular in this respect because a very large proportion of the trouble in the malleable foundry is due to it.

Starting with say 0.95 silicon, in the mixture if the heat is made sharp and short this silicon content will be lowered to the 0.65 required for the ordinary run of castings nicely, and it will drop from 0.65 to 0.60 from the beginning to the end of tapping, whereas with a long, slow melting the iron may be 0.65 at the beginning of tapping and down to 0.55 at the end of the heat or a loss of twice the silicon. And when this occurs the iron has begun to oxidize. Another thing: Take a bath of iron in the air furnace which is deep near the bridge, and feathers out to nothing at the stack. If there is any one thing dangerous in the air furnace it is that thin, feather edge at the end; because there all the gases are swept over it, and the heat is transmitted into a very thin body of metal. Consequently, the temperature rises very fast at that spot; and the iron is liable to burn.

.I have been preaching for many years that iron oxidizes in every melting process, even if ever so slightly. The worst case I ever came across contained only three-hundredths of one per cent of oxygen. Such iron is unfit for use, for the simple reasonthat the freezing point has been raised; the iron sets too quick. It has lost its "life." In ninety-nine cases out of a hundred the troubles found in malleable castings practice may be located right here. If we study the papers on malleable we have seen recently we find a number of statements on the behavior of castings under certain conditions. These seem to me doubtful, as they may be based on metal that was oxidized in the making in the first place and showed characteristics afterwards which they would not have had they been made right. Air furnaces, which are in prevailing use for "malleable," are subject to this danger peculiarly, and hence must be watched so that heats are made in the shortest time possible.

I have made about 225,000 tons of malleable castings myself, and most of them in the Open Hearth furnace. It is to my mind the best melting process except the obsolete crucible and the electric, of which we know little now but will hear more of some day. The Open Hearth furnace melting process is only applicable where there is enough work to keep the furnace running steady. Look at the melting ratios: cupola, one to eight; air furnace, one to four under the best conditions (and the furnaces should always be kept in the best of condition); Open Hearth furnace, one to six

is the melting ratio. The air in the Open Hearth furnace instead of going in cold has about 1000° F. heat. Whereas a good heat of 10 tons in the air furnace may take four hours, we can run the same heat in two and a half hours in the open hearth (from the end of the charging to the beginning of the tapping).

Unfortunately in malleable and in gray iron we are dealing with lower temperatures than in steel making, and hence the addition of ferro-manganese does not accomplish deoxidation. Hence whereas in steel making the unavoidable oxidation is thus corrected, in the case of malleable and gray iron this is not possible to a sufficiently satisfactory extent. Hence prevention is what must be looked after and not a cure after the damage through oxidation has been accomplished.

In making malleable you have the following condition. A great big bath of molten iron, hot on top, and down on the bottom not quite so hot. You take your test plugs, the fracture shows crystalline and white; it indicates that the composition is right. When you tap you draw the colder iron from the bottom first. The top of your charge comes down maybe an hour later. In the meantime the oxidizing reaction goes on; the slag has been taken off; there is a direct contact with the gases, the metal is damaged. It should really be taken from the top first. The ideal method of getting iron out of an air furnace is to take it from the top. The tilting furnace gives this result. The tilting furnace costs about twice as much as the ordinary open hearth furnace. I therefore patented a three spout arrangement for my furnaces, thus taking off six or seven tons from the top; then the next six or seven tons below; then break the breast out and get the rest of it from the bottom. This gives the ideal condition of the tilting furnace in sufficient measure.

In my open hearth practice I never skim, but let the slag cover the iron, thus protecting it somewhat against oxidation.

The composition of a malleable casting, so far as the silicon is concerned depends on its thickness entirely. In ordinary work the silicon should be about 0.65. For very heavy work I used to run my silicon down to 0.45. In the old days of charcoal iron my regular silicon was 0.35 (charcoal iron could be used as low in silicon as 0.10). With coke irons it is not wise to have pig iron with less than 0.75 silicon in stock. This brings us back to the

question of oxidation again. In making cold blast charcoal iron you have a very small furnace to begin with; charcoal which eagerly absorbs oxygen as a fuel and hence the iron sponge formed melts with the least chance of oxidation. With the hot and more powerful blast, there is a little further penetration of free oxygen; with the consequent greater oxidation of the iron sponge as it melts, and hence a weaker iron. With coke fuel there is a very serious entrance of free oxygen. Coke does not unite with the oxygen in burning as fast as in the case with the charcoal. The difference between charcoal and coke irons lies only in this oxidation question. It is the basis of all the trouble we have with our bad castings, because I know that wherever I have changed the method or melting to eliminate chances for oxidation troubles have fallen away.

The next department to study is the sorting room.. The castings from the foundry are first run through the hard tumbling room to clean them; then sorted to find the defective ones. If the foreman knows his business, by watching this department he can teach each man to overcome his difficulties and the losses will be cut down in consequence.

Then the castings go to the anneal. In annealing the idea is to get the castings up to the annealing heat quick, hold them at annealing heat for a given time—sixty hours is best—then to let them cool gradually. The quicker you can get the heat up in your ovens the more time you can save. You can keep them in the annealing ovens sixty, seventy, eighty, ninety hours; but sixty is found to be about right; and the specifications usually call for that as a minimum. The process is best carried out by packing the castings in oxide of iron. The material that we use is puddle scale, a silicate and oxide of iron. The material I found best and cheapest to use was the flakes from the pots. They are almost pure iron oxide. There are other methods used on occasion. In some of our railroad work, tie plates for instance, these castings can be put loose in the oven, practically making a retort of this and use no packing whatever. But the castings look rough when they came out but are good enough for the purpose.

As to temperature of the anneal—the old-fashioned way of looking at the cracks in the brick work to see the white line is very good if the eye of a man does not change. I prefer the

LeChatelier pyrometer. The temperature should be taken at the coldest point of the coldest pot in the oven and not the temperature of the oven itself.

The temperature at the coldest point of the coldest pot should be 1350° F.; it may go as low as 1250 or it may be as high as 1400. For cupola iron, the temperature must be about 200 degrees higher, because of the fact that the iron was melted in contact with the fuel, and has a higher sulphur content, which obstructs the annealing changes at lower temperatures.

There is much more that could be said on this subject. It is a life work to become familiar with all the peculiarities of this single line of the iron casting industry. Enough, however, has been given to show what an interesting field the production of the Malleable Casting is, and how much there is still to be learned in this direction.

CONSTITUTION

AND

MEMBERSHIP LIST

CONVENTIONS OF THE AMERICAN FOUNDRYMEN'S ASSOCIATION

Year.	Convention City.	President.
1896.	Philadelphia	*Francis Schuman, Philadelphia, Pa.
1897.	Detroit	*Francis Schuman, Philadelphia, Pa.
1898.	Cincinnati	*Francis Schuman, Philadelphia, Pa.
1899.	Pittsburgh	*C. S. Bell, Hillsboro, O.
1900.	Chicago	J. S. Seaman, Pittsburgh, Pa.
1901.	Buffalo	W. A. Jones, Chicago, Ill.
1902.	Boston	*J. S. Sadlier, Springfield, O.
1903.	Milwaukee	A. W. Walker, Boston, Mass.
1904.	Indianapolis	Willis Brown, Buffalo, N. Y.
1905.	New York	Chris. J. Wolff, Chicago, Ill.
1906.	Cleveland	Thos. D. West, Cleveland, O.
1907.	Philadelphia	W. H. McFadden, Ponca City, Okla.
1908.	Toronto	Stanley G. Flagg, Jr., Philadelphia, Pa.
1909.	Cincinnati	L. L. Anthes, Toronto, Ont.
1910.	Detroit	Arthur T. Waterfall, Detroit, Mich.
1911.	Pittsburgh	Maj. Jos. T. Speer, Pittsburgh, Pa.
1912.	Buffalo	Maj. Jos. T. Speer, Pittsburgh, Pa.
1913.	Chicago	H. D. Miles, Buffalo, N. Y.

* Deceased.

VICE-PRESIDENTS.

Anthes, L. L.	Toronto, Ont.	1906, 1907.
Anthony, E. W.	Boston, Mass.	1904.
Bair, Adam	Milwaukee, Wis.	1902, 1903, 1905.
*Bauer, C. A.	Springfield, O.	1898, 1899, 1901.
Beckett, J. A.	Hoosick Falls, N. Y.	1902, 1903.
Beckwith, A. K.	Dowagiac, Mich.	1903, 1904, 1905.
*Bell, C. S.	Hillsboro, O.	1897.
Best, T. J.	Montreal, P. Q.	1896, 1897, 1898, 1899, 1900, 1901, 1902, 1903, 1904, 1905.
Bole, Wm. A.	Pittsburgh, Pa.	1910.
Buckingham, Geo. B.	Worcester, Mass.	1900.
Bull, R. A.	Granite City, Ill.	1911, 1912.
Burr, J. W.	Brooklyn, N. Y.	1906, 1907.
Caley, C. J.	New Britain, Conn.	1906, 1907.
Carpenter, Henry R.	Providence, R. I.	1905.
Chadsey, S. B.	Toronto, Ont.	1911, 1912.
Chartrey, R.	San Francisco, Cal.	1898, 1899, 1900.
Clare, A. N. W.	Preston, Ont.	1909, 1910.
Cluff, R. J.	Toronto, Ont.	1908.
Colvin, T. H.	Providence, R. I.	1901.
Diller, H. E.	Erie, Pa.	1904.
Evans, Henry C.	Chattanooga, Tenn.	1896.
Farnsworth, F. B.	New Haven, Conn.	1908, 1909, 1910, 1911, 1912.
Ferguson, Wm.	Chicago, Ill.	1900.
Field, H. E.	Pittsburgh, Pa.	1907.
Findley, A. I.	Cleveland, O.	1902.

* Deceased.

Flagg, Stanley G., Jr	Philadelphia, Pa	1906.
Frank, I. N	Pittsburgh, Pa	1897, 1898.
Gibby, F. W	Boston, Mass	1896.
Gilbert, Wm	Cincinnati, O	1909, 1910.
Gilmour, E. P	Milwaukee, Wis	1901.
Golden, J. P	Columbus, Ga	1899, 1900, 1901, 1902, 1903, 1904, 1905, 1906, 1907.
Howell, Alfred E	Nashville, Tenn	1909, 1910, 1911, 1912.
Jeffrey, J. W	Columbus, O	1908.
Johnston, S. T	Chicago, Ill	1908.
Jones, W. A	Chicago, Ill	1899.
Keep, W. J	Detroit, Mich	1906.
*Kissick, J. W	Columbus, Ga	1908.
Lanigan, J. F	Lawrence, Mass	1902.
Lombard, G. R	Augusta, Ga	1911, 1912.
Magee, John	Chelsea, Mass	1903.
*McLaren, John	Pittsburgh, Pa	1903.
Miles, H. D	Buffalo, N. Y	1911.
*Mills, John	Port Chester, N. Y	1904.
Moldenke, Dr. R	Pittsburgh, Pa	1899.
Mosher, W. S	Dallas, Tex	1896, 1897, 1898, 1899, 1900.
Newcomb, C. L	Holyoke, Mass	1898.
Parry, Wm. H	Brooklyn, N. Y	1908.
Penton, John A	Detroit, Mich	1900.
Prince, W. F	Elizabethport, N. J	1901.
Putnam, E. H	Moline, Ill	1897, 1898.
Richmond, T. L	Buffalo, N. Y	1912.

* Deceased.

Scott, Irving	San Francisco, Cal.	1896.
Sessions, W. E.	Bristol, Conn.	1897.
Sheriff, T. J.	Milwaukee, Wis.	1904, 1906, 1907, 1908, 1909, 1910, 1911, 1912.
Sleeth, S. D.	Pittsburgh, Pa.	1901.
*Slocum, A. V.	Pittsburgh, Pa.	1905.
Smith, Eugene	Chicago, Ill.	1901, 1909.
Speer, Maj. Jos. T.	Pittsburgh, Pa.	1909.
Spence, David	Chicago, Ill.	1905.
Sweeney, J. M.	Chicago, Ill.	1896.
Taylor, Robt. G.	Pittsburgh, Pa.	1896.
*Thomas, D. J.	Pittsburgh, Pa.	1904.
Van Atta, H.	New York, N. Y.	1905.
Walker, A. W.	Boston, Mass.	1899.
Whiting, J. H.	Chicago, Ill.	1906.
Wilson, J. W.	Detroit, Mich.	1910.
Wolff, Chris. J.	Chicago, Ill.	1897, 1902, 1903.
Wood, Walter	Philadelphia, Pa.	1909, 1910, 1911, 1912.
Yagle, Wm.	Pittsburgh, Pa.	1900.
Zimmers, F. H.	Pittsburgh, Pa.	1902.

TREASURERS.

Howard Evans	Philadelphia, Pa.	1896 to 1900.
Thos. D. West	Cleveland, O.	1901.
Willis Brown	Buffalo, N. Y.	1902.
Dr. Richard Moldenke	Watchung, N. J.	1903 to date.

SECRETARIES.

John A. Penton	Cleveland, O.	1896 to 1899.
Dr. Richard Moldenke	Watchung, N. J.	1900 to date.

* Deceased.

CONSTITUTION OF THE AMERICAN FOUNDRYMEN'S ASSOCIATION

ARTICLE I.

Name and Object.

SECTION 1. This Association shall be known as the American Foundrymen's Association.

SEC. 2. The objects of this Association shall be the advancement of the interests of foundry operators, or all who are concerned in the casting of any kind of metal in sand, or loam molds, for any purpose; to collect for use of the Association all proper information connected with the foundry business; to exchange experience and encourage uniform customs and actions among foundrymen.

ARTICLE II.

Membership.

SECTION 1. The membership of this Association shall consist of three classes to be called respectively, active, associate, and honorary members.

SEC. 2. Any person, firm or corporation, engaged in the production of castings of any kind, as employer, superintendent, foreman, or chemist, may be elected an active member; and any associate member may become an active member when recommended by the Executive Board and approved by a majority vote of the Association at any regular meeting.

SEC. 3. Any person whose knowledge or services are valuable toward the objects of this Association may be elected an Associate Member. Associate Members shall have all the rights of active membership except the power to vote.

SEC. 4. Any individual whose knowledge or services, in connection with the objects of this Association, which have made him preeminent among his fellows, may be elected an honorary member.

ARTICLE III.

SECTION 1. The officers of this Association shall consist of a President, eight Vice-Presidents, and a Secretary-Treasurer; who shall with the Past-Presidents of this Association, form its Executive Board.

The Vice-Presidents shall elect one of their number as Senior Vice-President.

ARTICLE IV.

SECTION 1. There shall be an annual meeting of this Association, the date and location of which shall be fixed by the Executive Board at least three months in advance of the said meeting.

Twenty-five members shall constitute a quorum of the Association.

SEC. 2. Meetings of the Executive Board may be called by the President or by any three members of said Board, and five members shall constitute a quorum.

ARTICLE V.

SECTION 1. This constitution may be amended at any regular meeting of the Association by a two-thirds vote of the members present, provided the Secretary—through letter ballot submitted to all active members within 30 days after adjournment—shall secure in 30 days after the submission of said letter ballot to the members, a ratification of an amendment by a majority of those returning letter ballot, signed by those voting.

BY-LAWS

Duties of Officers.

SECTION 1. The duties of the president shall be to preside at the meetings of the Association and of the Executive Board, and to perform such other duties as usually devolve upon a presiding officer.

SEC. 2. The Senior Vice-President shall perform the duties of the President when the latter is absent or unable to perform the same, or in case of vacancy in the office of the President.

SEC. 3. The duties of the Secretary shall be to keep a full and accurate record of the proceedings of the Association and Executive Board, to make an annual report at the annual meeting, showing the number of active, associate and honorary members of the Association, the amount of dues collected, and the orders issued on the Treasurer, and he shall perform such other duties as may be assigned to him by the President or Executive Board.

SEC. 4. The duties of the Treasurer shall be to take charge of all funds of the Association, and pay them out only upon the order of the Secretary, countersigned by the President; he shall report at the annual meeting his receipts and disbursements for the year, in detail; he shall give a bond, the amount of which is to be fixed by the Executive Board.

SEC. 5. It shall be the duty of the Executive Board to manage the affairs of the Association to the best of their ability.

Membership.

SEC. 6. All applications for membership shall be made to the Secretary.

SEC. 7. On the first day of each month the Secretary shall mail to each member of the Executive Board a list of applicants for membership. If he shall not receive, by the 15th day of the same month, the written protest of two of the members of the Executive Board to any application, he shall then enroll the said applicants as members of the Association, and notify them at once of their election.

Dues.

SEC. 8. The annual dues for each active or associate member of the Association shall be $10.00, which shall be due and payable annually in the month of July.

SEC. 9. No dues or assessments of any kind shall be collected from honorary members.

Elections.

SEC. 10. All officers of the Association shall be elected by ballot by the active members of the Association at its annual meeting; a majority vote of those voting being necessary to elect.

SEC. 11. All officers of the Association shall hold office for one year from the adjournment of the annual meeting at which they are elected, and until their successors shall have been elected. In the case of a vacancy occurring in any office during the year, the Executive Board shall fill the vacancy for the unexpired term.

Order of Business.

SEC. 12. The order of business to be observed at annual meetings shall be as follows:

(1) Reading of the minutes of the last meeting.

(2) Announcement by the President of special committees, as follows:

A committee of five to nominate officers for the following year.

A committee of three to audit the accounts of the Secretary-Treasurer.

A committee of five to report on papers to be presented to the Association.

(3) Report of officers and standing committees.

(4) Report of special committees.

(5) Unfinished business.

(6) New business.

(7) Election of officers.

Amendments.

SEC. 13. These by-laws may be amended at any regular meeting of the Association by a two-thirds vote of the members present, provided the Secretary—through letter ballot submitted to all active members within 30 days after adjournment—shall secure in 30 days after the submission of said letter ballot to the members, a ratification of an amendment by a majority of those returning letter ballot, signed by those voting.

Rules of Order.

SEC. 14. Roberts' Parliamentary Rules of Order shall be recognized as authority by this Association.

OFFICERS OF THE ASSOCIATION FOR 1912–1913.

President: H. D. MILES,
Buffalo Foundry and Machine Company, Buffalo, N. Y.

Senior Vice-President: ALFRED E. HOWELL,
Phillips & Buttorff Manufacturing Company, Nashville, Tenn.

Vice-President: F. B. FARNSWORTH,
McLagon Foundry Company, New Haven, Conn.

Vice-President: T. L. RICHMOND,
Buffalo Scale Company, Buffalo, N. Y.

Vice-President: WALTER WOOD,
R. D. Wood & Co., Philadelphia, Pa.

Vice-President: R. A. BULL,
Commonwealth Steel Company, Granite City, Ill.

Vice-President: T. W. SHERIFF,
Sheriff Manufacturing Company, Milwaukee, Wis.

Vice-President: G. R. LOMBARD,
Lombard Iron Works and Supply Company, Augusta, Ga.

Vice-President: S. B. CHADSEY,
Massey-Harris Company, Limited, Toronto, Ont.

Secretary-Treasurer: DR. RICHARD MOLDENKE,
Watchung, N. J.

HONORARY MEMBERS.

ELECTED.

1910. ANTHES, L. L. Anthes Foundry, Limited, Winnipeg, Manitoba.

1905. BROWN, WILLIS. 534 Main Street, Buffalo, N. Y.

1909. FLAGG, STANLEY G., JR. Stanley G. Flagg & Co., Philadelphia, Pa.

1902. JONES, W. A. W. A. Jones Foundry and Machine Company, Chicago, Ill.

1908. MCFADDEN, W. H. Ponca City, Okla.

1907. MOLDENKE, DR. RICHARD. Watchung, N. J.

1901. SEAMAN, J. S. Seaman-Sleeth Company, Pittsburgh, Pa.

1912. SPEER, MAJ. JOS. T. Pittsburgh Valve, Foundry and Construction Company, Pittsburgh, Pa.

1901. TURNER, PROF. THOMAS. The University, Birmingham, England.

1904. WALKER, A. W. Walker & Pratt Manufacturing Company, Boston, Mass.

1911. WATERFALL, ARTHUR T. Russel Wheel and Foundry Company, Detroit, Mich.

1907. WEST, THOS. D. The West Steel Casting Company, Cleveland, O.

1906. WOLFF, CHRIS. J. L. Wolff Manufacturing Company, Chicago, Ill.

MEMBERS.

1896. Abendroth Brothers. Port Chester, N. Y.
1907. Acme Foundry Company, The. Cleveland, O.
1908. Acme Steel and Malleable Works. Buffalo, N. Y.
1907. Adriance, Platt & Co. Poughkeepsie, N. Y.
1912. Adrian Furnace Company. Du Bois, Pa.
1896. Aermotor Company. Twelfth and Rockwell Streets, Chicago, Ill.
1913. Alabama Company, The. J. W. Porter, General Sales Agent, Birmingham, Ala.
1909. Alamo Iron Works. San Antonio, Tex.
1907. Aland, Charles M. Coshocton, O.
1909. Alberger Pump and Condenser Company. Newburgh, N. Y.
1907. Allan, Andrew, Jr. 486 Greenwich Street, New York City.
1908. Allen Company, Charles G. Barre, Mass.
1912. Alling, Edward B. Box 175, New Britain, Conn.
1908. American Blower Company. Detroit, Mich.
1907. American Clay Machinery Company, The. Willoughby, O.
1909. American Engineering Company. Aramingo Avenue and Cumberland Street, Philadelphia, Pa.
1908. Amherst Foundry Company, Limited. Amherst, N. S.
1900. American and British Manufacturing Company. Providence, R. I.
1912. American Brake Shoe and Foundry Company. Mahwah, N. J.
1912. American Car and Foundry Company. Berwick, Pa.
1906. American Hardware Corporation, The. New Britain, Conn.
1910. American Hoist and Derrick Company. St. Paul, Minn.
1907. American Laundry Machinery Company. Rochester, N. Y.

1908. American Lumber and Manufacturing Company. Pittsburgh, Pa.

1907. American Saw Mill Machinery Company. Hackettstown, N. J.

1908. American Seeding Machine Company. Springfield, O.

1906. American Steel Foundries. Commercial National Bank Building, Chicago, Ill.

1911. American Vanadium Company. Frick Building, Pittsburgh, Pa.

1907. American Wood Working Machinery Company. Rochester, N. Y.

1910. Anaconda Copper Mining Company. Anaconda, Mont.

1904. Anthes Foundry, Limited. Toronto, Ont.

1904. Antisell, F. L., Raritan Copper Works. Perth Amboy, N. J.

1907. Arcade Manufacturing Company. Freeport, Ill.

1912. Atlantic Foundry Company, The. Akron, O.

1912. Atlantic Radiator Company. 925 Chestnut Street, Philadelphia, Pa.

1907. Backert, A. O., Penton Publishing Company. Cleveland, O.

1908. Baird & West. Detroit, Mich.

1896. Barbour-Stockwell Company. Cambridgeport, Mass.

1912. Barlow Foundry Company. Newark, N. J.

1907. Barnett, Oscar, Foundry Company. Newark, N. J.

1908. Barstow Stove Company. Providence, R. I.

1908. Bartley, Jonathan, Crucible Company. Trenton, N. J.

1910. Bass Foundry and Machine Company, The. Fort Wayne, Ind.

1908. Barnum, S. H. New Haven, Conn.

1909. Bay View Foundry Company, The. Sandusky, O.

1896. Beckett, James A. Hoosick Falls, N. Y.

1900. Beckwith, P. D., Estate of. Dowagiac, Mich.

1907. Belle City Malleable Iron Company. Racine, Wis.

1907. Bell Company, The C. S. Hillsboro, O.

1908. Belleville Stove and Range Company. Belleville, Ill.

1913. Benton Harbor Malleable Foundry Company. Benton Harbor, Mich.

1907. Berkshire Manufacturing Company. Cleveland, O.
1911. Berkshire Pattern Company. Pittsfield, Mass.
1908. Berlin Machine Works. Beloit, Wis.
1908. Bertram & Sons Co., Limited, The John. Dundas, Ont.
1911. Bessemer Coke Company. Pittsburgh, Pa.
1896. Best, T. J., Warden, King, Limited. Montreal, P. Q.
1897. Bethlehem Foundry and Machine Company. South Bethlehem, Pa.
1905 Bethlehem Steel Company. South Bethlehem, Pa.
1909. Bettendorf, J. W. President, Bettendorf Axle Company. Bettendorf, Ia.
1896. Birmingham Iron Foundry. Derby, Conn.
1912. Birmingham Machine and Foundry Company. Birmingham, Ala.
1909. Birkenstein & Sons, S. 344 West Ontario Street, Chicago, Ill.
1911. Blairsville Enameled Ware Company. Blairsville, Pa.
1907. Blundell, Fred. Box 128, P. O. Station "B," Cleveland, O.
1903. Booth, Garrett & Blair. 406 Locust Street, Philadelphia, Pa.
1908. Bowmanville Foundry Company, Limited, The. Bowmanville, Ont.
1908. Bracken, H. W. Hopedale, Mass.
1901. Braddock Machinery and Manufacturing Company. Braddock, Pa.
1908. Bradley Manufacturing Company Works, David. Bradley, Ill.
1907. Brakes, James. Lyon Mountain, N. Y.
1910. Brasseur, Jules. 356 Avenue Louise, Brussels, Belgium.
1907. Braucher, Peter S. P. & R. Locomotive Shops, Reading, Pa.
1913. Braun & Sons, John. 1615 North Twenty-third Street, Philadelphia, Pa.
1912. Bridge & Beach Manufacturing Company. 503 South First Street, St. Louis, Mo.
1913. Brillion Iron Works. Brillion, Wis.

1896. BROADWAY IRON FOUNDRY. Cambridgeport, Mass.
1907. BROMLEY, F. L. President, American Motor Castings Company, Detroit, Mich.
1912. BROWN, I. G. 426 Broadway, Waukesha, Wis.
1906. BROWN & CO., E. E. McKean and Meadow Streets, Philadelphia, Pa.
1896. BROWN & SHARPE MANUFACTURING COMPANY. Providence, R. I.
1910. BUCHANAN, JUDSON. Chattanooga Plow Company, Chattanooga, Tenn.
1912. BUCHANAN ELECTRIC STEEL COMPANY. Buchanan, Mich.
1907. BUCHANAN FOUNDRY COMPANY, THE. Lebanon, Pa.
1907. BUCH'S SONS, A. Elizabethtown, Pa.
1907. BUCKEYE ENGINE COMPANY. Salem, O.
1907. BUCKEYE FOUNDRY COMPANY, THE. Buck Street, Cincinnati, O.
1911. BUCKEYE STEEL CASTING COMPANY, THE. Columbus, O.
1912. BUCKS STOVE AND RANGE COMPANY. 3500 North Second Street, St. Louis, Mo.
1913. BUCKWALTER STOVE COMPANY. Royersford, Pa.
1907. BUCYRUS COMPANY, THE. South Milwaukee, Wis.
1909. BUCYRUS STEEL CASTING COMPANY, THE. Bucyrus, O.
1911. BUFFALO FORGE COMPANY. Buffalo, N. Y.
1905. BUFFALO FOUNDRY AND MACHINE COMPANY. Buffalo, N. Y.
1912. BUFFALO SCALE COMPANY. Buffalo, N. Y.
1907. BULL, R. A. Commonwealth Steel Company, Granite City, Ill.
1898. BURR & HOUSTON CO., THE. 84 Calyer Street, Brooklyn, N. Y.

1906. CAHILL IRON WORKS, THE. Chattanooga, Tenn.
1909. CALDWELL & SON CO., H. W. Seventeenth Street and Western Avenue, Chicago, Ill.
1910. CAMP & SONS COMPANY, INCORPORATED, E. N. Moreland, Ga.
1912. CANADA MACHINERY COMPANY, LIMITED. Galt, Ont.
1907. CANADIAN LOCOMOTIVE COMPANY. Kingston, Ont.
1912. CANADIAN RUMELY COMPANY, LIMITED, THE. 48 Abelle Street, Toronto, Ont.

1911. CANADIAN STEEL FOUNDRIES, LIMITED. Montreal, P. Q.
1913. CARBON STEEL CASTING COMPANY. Lancaster, Pa.
1900. CARONDELET FOUNDRY COMPANY. 2123 South Kingshighway, St. Louis, Mo.
1904. CARR & CO., STEWART R. Baltimore, Md.
1908. CASE PLOW WORKS, J. I.. Racine, Wis.
1908. CENTRAL FOUNDRY COMPANY. 90 West Street, New York City.
1909. CENTRAL IRON WORKS. Quincy, Ill.
1910. CENTRAL RADIATOR COMPANY. Lansdale, Pa.
1901. CHAIN BELT COMPANY. Milwaukee, Wis.
1908. CHAPMAN'S SONS COMPANY, T. M. Old Town, Me.
1911. CHAPMAN VALVE MANUFACTURING COMPANY. Indian Orchard, Mass.
1911. CHATTANOOGA ROOFING AND FOUNDRY COMPANY. Chattanooga, Tenn.
1907. CHENEY & SON, S. Manlius, N. Y.
1907. CHICAGO PNEUMATIC TOOL COMPANY. 277 Dearborn Street, Chicago, Ill.
1913. CHICAGO STEEL FOUNDRY COMPANY. Kedzie Avenue and Thirty-seventh Street, Chicago, Ill.
1908. CHISHOLM & MOORE MANUFACTURING COMPANY, THE. Cleveland, O.
1906. CITY FOUNDRY COMPANY, THE. Cleveland, O.
1908. CLARE BROTHERS & CO., LIMITED. Preston, Ont.
1908. CLARK BROTHERS COMPANY. Belmont, N. Y.
1912. CLARKSVILLE FOUNDRY AND MACHINE WORKS. Clarksville, Tenn.
1910. CLELAND, J. H. Meaford, Ont.
1900. CLINTON IRON AND STEEL COMPANY. Pittsburgh, Pa.
1913. CLOW & SONS, JAMES B. Coshocton, O.
1908. COCKSHUTT PLOW COMPANY, LIMITED. Brantford, Ont.
1896. COLORADO FUEL AND IRON COMPANY, THE. Pueblo, Col.
1897. COLORADO IRON WORKS COMPANY. Denver, Col.
1907. COLUMBUS IRON AND STEEL COMPANY, THE. Columbus, O.
1907. COLUMBUS IRON WORKS COMPANY. Columbus, Ga.
1912. COLUMBUS MACHINE AND TOOL COMPANY, THE. Columbus, O.
1911. COLUMBIA STEEL COMPANY. San Francisco, Cal.

1896. COLVIN FOUNDRY COMPANY. Providence, R. I.
1912. COMMONWEALTH STEEL COMPANY. St. Louis, Mo.
1912. COMPANIE DESJARDINS, LA. St. André de Kamouraska, P. Q.
1906. CONNERSVILLE BLOWER COMPANY, THE. Connersville, Ind.
1912. COOPER BROTHERS. Cortlandt, N. J.
1896. CO-OPERATIVE FOUNDRY COMPANY. Rochester, N. Y.
1897. COX STOVE COMPANY, ABRAM. American and Dauphin Streets, Philadelphia, Pa.
1896. CRANE COMPANY. 1214 South Canal Street, Chicago, Ill.
1900. CRANE COMPANY, WILLIAM M. Gates and Garfield Avenues, Jersey City, N. J.
1900. CRANE IRON WORKS. Catasauqua, Pa.
1911. CRANE VALVE COMPANY. Bridgeport, Conn.
1908. CROOK, ALFRED. Twenty-third Street and Washington Avenue, Philadelphia, Pa.
1907. CROWELL & MURRAY. Perry Payne Building, Cleveland, O.
1908. CROZIER, J. J. Kennett Square, Pa.
1909. CUMBERLAND FOUNDRY AND MANUFACTURING COMPANY. West Nashville, Tenn.
1908. CURTENIUS, D. R. Kalamazoo Stove Company, Kalamazoo, Mich.
1908. CURTIS & CO. MANUFACTURING COMPANY. Wellston P. O., St. Louis, Mo.

1913. DAIN MANUFACTURING COMPANY, LIMITED. Welland, Ont.
1900. DAMASCUS BRONZE COMPANY. South Avenue and Sturgeon Street, Pittsburgh, Pa., N. S.
1907. DANVILLE FOUNDRY AND MACHINE COMPANY. Clarence E. Haupt, Danville, Pa.
1912. DARBYSHIRE-HARVIE IRON AND MACHINE COMPANY. El Paso, Tex.
1910. DAVENPORT & KEELER. New Britain, Conn.
1912. DAVENPORT MACHINE AND FOUNDRY COMPANY. Davenport, Ia.
1906. DAVIS, GEORGE C. 39 South Tenth Street, Philadelphia, Pa.

1898. Dawes & Miler Works. New Brighton, Pa.
1907. Debevoise-Anderson Company. 95 Liberty Street, New York City.
1910. Deere & Co. Moline, Ill.
1908. Deming Company, The. Salem, O.
1912. Dempster Mill Manufacturing Company. Beatrice, Neb.
1912. Detroit Steel Casting Company. Detroit, Mich.
1906. Detroit Testing Laboratory, The. 674 Woodward Avenue, Detroit, Mich.
1904. Devlin Manufacturing Company, Thomas. Lehigh Avenue, Third and American Streets, Philadelphia, Pa.
1907. Dewey Brothers. Goldsboro, N. C.
1912. Dexter Folder Company. Pearl River, N. Y.
1901. Diller, H. E. General Electric Company, Erie, Pa.
1907. Dings Electromagnetic Separator Company. 675 South Street, Milwaukee, Wis.
1898. Dodge Manufacturing Company. Mishawaka, Ind.
1908. Dodge Manufacturing Company. Toronto, Ont.
1907. Douglas, W. & B. Middletown, Conn.
1909. Dover Fire Brick Company. Cuyahoga Building, Cleveland, O.
1909. Dowler, A. S. 723 Atlanta Avenue, Webster Groves, Mo.
1906. Drummond, E. M. Drummond Manufacturing Company, Louisville, Ky.
1912. Drysdale, Alexander T. Box 126, Sheffield, Ala.
1907. Duquesne Steel Foundry Company. Arrott Building, Pittsburgh, Pa.

1911. Eagle Casting Company. Winchester, Ky.
1911. Eastern Facing Mills, The. Williamsport, Pa.
1902. Eaton, F. M. Union Trust Building, Cincinnati, O.
1911. Electric Reduction Company, Limited, The. Buckingham, P. Q.
1906. Elmira Foundry Company. Elmira, N. Y.
1905. Emerson, Harrington. 30 Church Street, New York City.

1908. Emerson, Samuel D. I. 137 Corlies Avenue, Pelham, N. Y.
1908. Emerson Laboratory. 177 State Street, Springfield, Mass.
1912. Empire Foundry Company. New Brunswick, N. J.
1904. England, George. Edgar Thomson Foundries. Braddock, Pa.
1907. Enterprise Foundry Company. Detroit, Mich.
1912. Enterprise Manufacturing Company. Columbiana, O.
1896. Enterprise Manufacturing Company of Pennsylvania, The. Third and Dauphin Streets, Philadelphia, Pa.
1907. Enterprise Sand Company. Fulton Building, Pittsburgh, Pa.
1909. Epping-Carpenter Company. Forty-first Street and A. V. Ry., Pittsburgh, Pa.
1912. Erie Engine Works. Erie, Pa.
1900. Erie Foundry Company. Erie, Pa.
1912. Erie Malleable Iron Company. Erie, Pa.
1907. Estate Stove Company, The. Hamilton, O.
1912. Evans, B. F. 633 Washington Avenue, Dunkirk, N. Y.
1907. Eynon-Evans Manufacturing Company. Fifteenth and Clearfield Streets, Philadelphia, Pa.

1912. Fairbanks & Co., E. & T. St. Johnsbury, Vt.
1911. Fairbanks Company, The. Binghamton, N. Y.
1910. Fairbanks, Morse & Co. Beloit, Wis.
1913. Fairmont Mining Machinery Company. Fairmont, W. Va.
1901. Farrel Foundry and Machine Company. Ansonia, Conn.
1910. Favorite Stove and Range Company, The. Piqua, O.
1909. Federal Foundry Supply Company. Cleveland, O.
1910. Fell, Joseph E. 36 Lake Street, Ogdensburg, N. Y.
1910. Ferguson & Lange Foundry Company. Claybourne Avenue and Willow Street, Chicago, Ill.
1912. Ferro Machine and Foundry Company. Cleveland, O.
1899. Field, H. E. Mackintosh, Hemphill & Co., Pittsburgh, Pa.
1910. Findlay Brothers. Carlton Place, Ont.

1896. FLAGG & CO., STANLEY G. 1421 Chestnut Street, Philadelphia, Pa.

1908. FLEMING, JAMES. St. John, N. B.

1908. FLEURY'S SONS, J. Aurora, Ont.

1913. FLORENCE IRON WORKS. Florence, N. J.

1901. FORAN FOUNDRY AND MANUFACTURING COMPANY. Flemington, N. J.

1906. FORT PITT MALLEABLE IRON COMPANY. McKees Rocks, Pa.

1909. FORT PITT STEEL CASTING COMPANY. McKeesport, Pa.

1912. FOUNDRY AND MACHINE EXHIBITION COMPANY, THE. Lewis Institute, Chicago, Ill.

1908. FOX'S SONS, BENJAMIN. 513 West Thirty-fourth Street, New York City.

1910. FRANCIS, FRANK. Chester Steel Casting Company, Chester, Pa.

1911. FREESE & CO., A. M. Galion, O.

1900. FRENCH & HECHT. Davenport, Ia.

1900. FRENCH & HECHT. Springfield, O.

1898. FRICK COMPANY. Waynesboro, Pa.

1901. FROHMAN, ED. D. The S. Obermayer Company, Pittsburgh, Pa.

1912. FROST & WOOD CO., LIMITED, THE. Smith's Falls, Ont.

1904. FULLER, BENJAMIN D. Westinghouse Electric and Manufacturing Company, Cleveland, O.

1907. FULLER & WARREN CO. Troy, N. Y.

1906. FULTON FOUNDRY AND MACHINE COMPANY. 24 Furman Street, Brooklyn, N. Y.

1907. GAIBLE, JULIAN. The Brownell Company, Dayton, O.

1909. GAINESVILLE IRON WORKS. Gainesville, Ga.

1910. GALION IRON WORKS COMPANY, THE. Galion, O.

1907. GALT MALLEABLE IRON COMPANY, LIMITED, MESSRS. Galt, Ont.

1913. GALT STOVE AND FURNACE COMPANY, THE, LIMITED. Galt, Ont.

1896. GARDEN CITY SAND COMPANY, THE. Chamber of Commerce Building, Chicago, Ill.

1908. GARDNER PRINTING COMPANY, THE. Cleveland, O.

1904. Garrison Foundry Company, A. Ninth Street, S. S., Pittsburgh, Pa.
1897. General Electric Company. West Lynn, Mass.
1906. General Electric Company. Schenectady, N. Y.
1912. General Electric Company. Pittsfield, Mass.
1896. General Fire Extinguisher Company. Providence, R. I.
1896. Gibby Foundry Company. East Boston, Mass.
1908. Gibney, James W. 416 Woodward Avenue, Buffalo, N. Y.
1908. Gilbert, George McA. Carthage, N. Y.
1910. Gilbert, L. D. King Street, Waynesboro, Pa.
1903. Gilson Manufacturing Company. Port Washington, Wis.
1909. Girard Iron Company, The. Girard, O.
1907. Girard Iron Works. Twenty-second and Master Streets, Philadelphia, Pa.
1912. Glasgow, W. R. Traders Bank Building, Toronto, Ont.
1911. Glass, James. Wheeling Mold and Foundry Company, Wheeling, W. Va.
1907. Gleason Works. Rochester, N. Y.
1913. Globe Foundry and Machine Company. Globe, Ariz.
1908. Goldie & McCullough Company, The. Galt, Ont.
1898. Golden's Foundry and Machine Company. Columbus, Ga.
1904. Goldschmidt Thermit Company, The. 90 West Street, New York City.
1912. Goodison Thresher Company, Limited, The John. Sarnia, Ont.
1907. Goodnow Foundry Company, L. H. Fitchburg, Mass.
1898. Goulds Manufacturing Company, The. Seneca Falls, N. Y.
1907. Graceton Coke Company. Graceton, Pa.
1910. Graham Manufacturing Company, James. San Francisco, Cal.
1906. Gray & Dudley Hardware Company. Nashville, Tenn.
1913. Gray Iron Foundry Company. Reading, Pa.
1896. Green Fuel Economizer Company, The. Matteawan, N. Y.

1911. Greenlee Foundry Company. 662 West Twelfth Street, Chicago, Ill.

1912. Green's Car Wheel Manufacturing Company. 3018 North Broadway, St. Louis, Mo.

1905. Griffin Wheel Company. Sacramento Square, Chicago, Ill.

1911. Grote Manufacturing Company, The. Evansville, Ind.

1901. Hadfield, Sir Robert. 22 Carleton House Terrace, London, England.

1910. Hall, J. W. Apartado 198, San Luis Potosi, Mexico.

1908. Hall, Frank E. American Radiator Company, Buffalo, N. Y.

1908. Hamilton, H. V. The Steel Company of Canada, Hamilton, Ont.

1909. Hanna & Co., M. A. Oliver Building, Pittsburgh, Pa.

1904. Harbison-Walker Refractories Company. Pittsburgh, Pa.

1910. Harrisburg Foundry and Machine Company. Harrisburg, Pa.

1907. Harrison Safety Boiler Works. Seventeenth Street and Allegheny Avenue, Philadelphia, Pa.

1906. Hartford Laboratory, The. Hartford, Conn.

1908. Hauck Manufacturing Company. Richards Street and Hamilton Avenue, Brooklyn, N. Y.

1910. Haven Malleable Castings Company, The. Cincinnati, O.

1907. Hawley Down Draft Furnace Company, The. Easton, Pa.

1908. Heath Foundry and Manufacturing Company, The. Plymouth, O.

1910. Hedges Lincoln Iron Works. Lincoln, Neb.

1911. Helmick Foundry-Machine Company. Fairmont, W. Va.

1908. Hennessy Foundry Company, The. Springfield, O.

1913. Hermance Machine Company. Williamsport, Pa.

1907. Herrman Pneumatic Molding Machine Company. Zelienople, Pa.

1908. Hersey Company, Limited, Milton. 171 St. James Street, Montreal, P. Q.

1897. Hill & Griffith Company, The. Cincinnati, O.
1907. Hillis & Jones Company. Foundry Department, Wilmington, Del.
1908. Hillis & Sons, Limited. Halifax, N. S.
1903. Hillman & Son, J. H. Frick Building, Pittsburgh, Pa.
1912. Hopson & Chapin Manufacturing Company, The. New London, Conn.
1906. Hunt Company, C. W. West New Brighton, Staten Island, N. Y.
1907. Hunter Machine Company, James. North Adams, Mass.
1910. Hunt-Spiller Manufacturing Company. South Boston, Mass.

1912. Idaho National Harvester Company. Moscow, Idaho.
1912. Ideal Manufacturing Company, The. Detroit, Mich.
1906. Illinois Malleable Iron Company. 1801 Diversey Boulevard, Chicago, Ill.
1912. Independent Foundry Company. Portland, Ore.
1910. Industrial Works. Bay City, Mich.
1910. International Correspondence Schools. Scranton, Pa.
1906. International Heater Company. Utica, N. Y.
1913. Interstate Car Company. Indianapolis, Ind.
1905. Interstate Foundry Company, The. Cleveland, O.
1905. Interstate Sand Company. Zanesville, O.
1910. Iowa Malleable Iron Company. Fairfield, Ia.
1899. *Iron Age, The.* 239 West Thirty-ninth Street, New York City.
1908. Iron City Sanitary Manufacturing Company. 18 Wood Street, Pittsburgh, Pa.

1912. Jackson Company, Wm. H. 229 West Twenty-eighth Street, New York City.
1912. Jamieson, Maj. Charles C. Walter A. Wood M. & R. Co., Hoosick Falls, N. Y.
1907. Jamieson Coal and Coke Company. Oliver Building, Pittsburgh, Pa.
1909. Janesville Machine Company, The. Janesville, Wis.

1896. Jarecki Manufacturing Company. Erie, Pa.
1908. Jiles Company, The James. Thirty-eighth Street and Liberty Avenue, Pittsburgh, Pa.
1907. Johnson, Edward A. Wentworth Institute, Boston, Mass.
1912. Johnston Harvester Company, The. Batavia, N. Y.
1897. Jones Foundry and Machine Company, W. A. North Avenue and Noble Street, Chicago, Ill.
1912. Jones Hollow Ware Company. Baltimore, Md.
1905. Joseph, E. E. Washington, corner Perry Street, Buffalo, N. Y.
1904. Justice, D. G. P. 43 Division Street, Crafton, Pa.

1913. Katzmann, James S. 257 Main Street, Everett, Mass.
1912. Keller Manufacturing Company. Minneapolis, Minn.
1898. Kelley & Co., T. P. 544 West Twenty-second Street, New York City.
1900. Kelley Foundry and Machine Company. Goshen, Ind.
1909. Kellogg Company, The M. W. 117 West Side Avenue, Jersey City, N. J.
1911. Kennedy, Robert. University of Illinois, Champaign, Ill.
1908. Kennedy & Sons Company, Limited, The Wm. Owens Sound, Ont.
1906. Kennedy's Foundry and Baltimore Malleable Iron and Steel Casting Company, P. Charles and Wells Streets, Baltimore, Md.
1908. Kerr, H. O. Kerr Engine Company, Limited, Walkerville, Ont.
1906. Kewanee Boiler Company. Kewanee, Ill.
1912. Kilpatrick & Sons Foundry Company, Alexander. 1615 North Twelfth Street, St. Louis, Mo.
1913. Kinnear Manufacturing Company, The. Columbus, O.
1909. Kirk, Charles L. 6050 Jenkins Arcade, Pittsburgh, Pa.
1910. Kirk, Dr. Edward. 938 North Tenth Street, Philadelphia, Pa.
1896. Kittanning Iron and Steel Manufacturing Company. Kittanning, Pa.
1907. Klaus, W. G. Best Manufacturing Company, Pittsburgh, Pa.

1907. KNICKERBACKER, JOHN. Waterford, N. Y.
1911. KNOEPPEL, C. E. 761 West Delavan Avenue, Buffalo, N. Y.
1908. KNOWLTON, C. F. Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa., N. S.
1903. KOHLER SONS COMPANY, J. M. Sheboygan, Wis.
1906. KREUZPOINTNER, P. 1400 Third Avenue, Altoona, Pa.
1908. KROESCHELL BROTHERS COMPANY. 55 Erie Street, Chicago, Ill.

1911. LACK MALLEABLE IRON COMPANY. Paducah, Ky.
1907. LACONIA CAR COMPANY WORKS, THE. Laconia, N. H.
1907. LA CROSSE PLOW COMPANY. La Crosse, Wis.
1906. LACY COMPANY, JAMES C. 1401 Block Street, Baltimore, Md.
1912. LAKE SHORE ENGINE WORKS. Marquette, Mich.
1908. LAMB KNITTING MACHINE COMPANY. Chicopee Falls, Mass.
1907. LANDERS, FRARY & CLARK. New Britain, Conn.
1900. LANE, H. M. 18 Piquette Avenue, East Detroit, Mich.
1896. LANE MANUFACTURING COMPANY. Montpelier, Vt.
1896. LAWRENCE STEEL CASTING COMPANY. Thirty-second Street and Railroad Avenue, Pittsburgh, Pa.
1910. LAWTON COMPANY, THE C. A. De Pere, Brown County, Wis.
1912. LENNOX FURNACE COMPANY, THE. Marshalltown, Ia.
1911. LENOIR CAR WORKS. Lenoir City, Tenn.
1900. LEWIS FOUNDRY AND MACHINE COMPANY. Pittsburgh, Pa.
1913. LIBERTY FOUNDRY COMPANY. 7600 Reilly Avenue, St. Louis, Mo.
1905. LIDGERWOOD MANUFACTURING COMPANY. 96 Liberty Street, New York City.
1912. LIMA LOCOMOTIVE CORPORATION. Lima, O.
1896. LINCOLN & CO., GEORGE H. South Boston, Mass.
1900. LINDEMANN & HOVERSON COMPANY, A. J. Milwaukee, Wis.
1913. LINK BELT COMPANY. Thirty-ninth Street and Stewart Avenue, Chicago, Ill.

1908. Little, Incorporated, Arthur D. 93 Broad Street, Boston, Mass.
1910. Little, J. W. 9 Penn Street, Waynesboro, Pa.
1896. Lobdell Car Wheel Company. Wilmington, Del.
1907. Logan, John A. 303 Summit Street, Mt. Oliver Station, Pittsburgh, Pa.
1899. Lombard Iron Works and Supply Company. Augusta, Ga.
1910. Lord & Burnham Company. Irvington, N. Y.
1902. Loudon, Archie M. 455 Spaulding Street, Elmira, N. Y.

1907. MacKinnon Boiler and Machine Company. Bay City, Mich.
1912. Madco Foundry and Machine Company. Phœnixville, Pa.
1907. Madison Foundry Company, The. Cleveland, O.
1896. Magee Furnace Company. Chelsea, Mass.
1908. MaGirl, P. H. Bloomington, Ill.
1896. Maher & Flockhart. 60 Polk Street, Newark, N. J.
1896. Malleable Iron Fittings Company. Branford, Conn.
1913. Malleable Iron Range Company. Beaver Dam, Wis.
1906. Manufacturers Foundry Company, The. Waterbury, Conn.
1913. Marion Malleable Iron Works, The. Marion, Ind.
1912. Marion Steam Shovel Company, The. Marion, O.
1912. Maryland Steel Company. 1421 Chestnut Street, Philadelphia, Pa.
1905. Mason, O. M. Midland Steel Company, Pittsburgh, Pa.
1908. Massey-Harris Company. Toronto, Ont.
1911. Materne Manufacturing Company. Eighteenth and Gratiot Streets, St. Louis, Mo.
1907. Mattice, A. M. R. F. D. No. 5, Lockport, N. Y.
1908. McClary Manufacturing Company, The. London, Ont.
1900. McCone, Alexander J. President, Nevada Engineering Works, Reno, Nev.
1912. McConway & Torley Company, The. Forty-eighth Street and A. V. Ry., Pittsburgh, Pa.

1896. McCormick Company, J. S. Twenty-eighth Street and Railroad Avenue, Pittsburgh, Pa.
1907. McCrum-Howell Company, The. 103 Park Avenue, New York City.
1908. McDougall Company, Limited, The R. Galt, Ont.
1912. McEwen, H. A. The Wali Iron Works, Limited, New Liskeard, Ont.
1912. McGee Iron and Brass Foundry Company, Joseph. 51 Sixth Street, Long Island City, N. Y.
1900. McKeefrey & Co. Leetonia, O.
1898. McLagon Foundry Company, The. New Haven, Conn.
1911. McLain, David. Goldsmith Building, Milwaukee, Wis.
1909. McLain Company, The J. H. Canton, O.
1904. McLean, Edward. Pennsylvania Railroad, Altoona, Pa.
1907. McNab & Harlin Manufacturing Company. Paterson, N. J.
1911. Meadville Malleable Iron Company. Meadville, Pa.
1912. Medina Foundry Company, The. Medina, O.
1907. Meeker Foundry Company. 95 Clay Street, Newark, N. J.
1903. Mesta Machine Company. P. O. Box 1124, Pittsburgh, Pa.
1907. Metric Metal Works. Erie, Pa.
1910. Michigan Motor Castings Company. Flint, Mich.
1910. Michigan Steel Casting Company. 248 Guoin Street, Detroit, Mich.
1896. Michigan Stove Company. Detroit, Mich.
1908. Midland Engine Works Company. Midland, Ont.
1907. Milford Iron Foundry. Milford, Mass.
1907. Miller, C. M. The Superior Foundry Company, Cleveland, O.
1904. Miller's Products Company. Empire Building, Pittsburgh, Pa.
1911. Minneapolis Steel and Machinery Company. Minneapolis, Minn.
1912. Missouri Malleable Iron Company. East St. Louis, Mo.
1907. Modern Foundry Company, The. Cincinnati, O.
1907. Moffat, J. K. Moffat Stove Company, Weston, Ont.

1911. Mohr & Son, J. J. 210 Bullitt Building, Philadelphia, Pa.
1907. Molder, H. M. Best Foundry Company, Bedford, O.
1907. Moline Plow Company. Moline, Ill.
1905. Monessen Foundry and Machine Company. Monessen, Pa.
1909. Monitor Stove and Range Company, The. Cincinnati, O.
1906. Montgomery, L. E. American Bridge Company, Ambridge, Pa.
1908. Moody & Sons Company, The M. Terrebonne, P. Q.
1910. Mooney, J. F. 1063 Harrison Avenue, Columbus, Ga.
1909. Moore & Sons Corporation, Samuel L. Elizabeth, N. J.
1896. Moore Brothers Company. Joliet, Ill.
1907. Moran, James. 414 Arcade Building, Philadelphia, Pa.
1910. Morgan Engineering Company. Alliance, O.
1912. Morris Company, I. P. Philadelphia, Pa.
1907. Morris Foundry Company, The John B. Cincinnati, O.
1912. Morse Chain Company. Ithaca, N. Y.
1896. Mott Company, J. L. Trenton, N. J.
1904. Mount Carbon Company, The. Powellton, W. Va.
1907. Mueller, Philip. Decatur, Ill.
1906. Mullen, John. Shamokin, Pa.
1906. Mumford Molding Machine Company. 30 Church Street, New York City.
1910. Munnoch, P. Mahwah, N. J.
1908. Murphy, M. F. American Locomotive Company, Schenectady, N. Y.
1907. Murphy Iron Works. Detroit, Mich.
1911. Murray, Arthur F. Blake & Knowles Steam Pump Company, East Cambridge, Mass.
1912. Murray Iron Works. Burlington, Ia.

1901. National Car Wheel Company. Pittsburgh, Pa.
1909. National Core Oil Company. Buffalo, N. Y.
1901. National Gear Wheel Company. South Avenue and Walker Street, Pittsburgh, Pa., N. S.
1909. National Roll and Foundry Company, The. Avonmore, Pa.

1912. NATIONAL SANITARY MANUFACTURING COMPANY, THE. Salem, O.

1910. NATIONAL SUPPLY COMPANY, THE. Station "B," Toledo, O.

1900. NATIONAL TUBE COMPANY. Kewanee Works, Kewanee, Ill.

1908. NELSON VALVE COMPANY. Chestnut Hill, Philadelphia, Pa.

1907. NEWBURY, J. H. Goshen, N. Y.

1907. NEWBURY MANUFACTURING COMPANY, THE. Monroe, N. Y.

1896. NEW ENGLAND BUTT COMPANY. Providence, R. I.

1911. NEW HAVEN SAND BLAST COMPANY. 47 Orange Street, New Haven, Conn.

1909. NEWPORT SAND BANK COMPANY. Newport, Ky.

1898. NEW YORK AIR BRAKE COMPANY, THE. Watertown, N. Y.

1906. NILES-BEMENT-POND COMPANY. Twenty-first and Callowhill Streets, Philadelphia, Pa.

1897. NILES TOOL WORKS COMPANY, THE. Hamilton, O.

1907. NORTH & JUDD MANUFACTURING COMPANY. New Britain, Conn.

1907. NORTHERN ENGINEERING WORKS. Detroit, Mich.

1912. NORTHERN MALLEABLE IRON COMPANY. St. Paul, Minn.

1911. NORTON COMPANY. Worcester, Mass.

1911. NOVELTY IRON COMPANY, THE. Canton, O.

1908. NOVO ENGINE COMPANY. Lansing, Mich.

1909. OBERHELMAN FOUNDRY COMPANY, J. A. Cincinnati, O.

1907. OBER MANUFACTURING COMPANY. Chagrin Falls, O.

1896. OBERMAYER COMPANY, THE S. Cincinnati, O.

1912. OHIO FOUNDRY COMPANY, THE. 2469 East Seventy-first Street, Cleveland, O.

1907. OHIO MALLEABLE IRON COMPANY, THE. Columbus, O.

1909. OIL WELL SUPPLY COMPANY. Oil City, Pa.

1905. OLIVER MACHINERY COMPANY. Grand Rapids, Mich.

1911. OLIVE STOVE WORKS. Rochester, Pa.

1910. ONTARIO MALLEABLE IRON COMPANY, LIMITED, THE. Oshawa, Ont.

1908. ONTARIO WIND ENGINE AND PUMP COMPANY. Toronto, Ont.

1912. Orbon Stove and Range Company. Belleville, Ill.
1899. Ormrod, John D. Emaus, Pa.
1907. Osborn Manufacturing Company, The. Cleveland, O.
1911. Otis Steel Company. Cleveland, O.

1913. Pacific Foundry Company. San Francisco, Cal.
1907. Palmers & De Mooy Foundry Company, The. Cleveland, O.
1905. Pangborn Company, Thomas W. Hagerstown, Md.
1909. Parker Brothers Company, Limited. Detroit, Mich.
1902. Parry, William H. 664 East Thirty-first Street, Brooklyn, N. Y.
1909. Patch, Incorporated, A. H. Clarksville, Tenn.
1898. Pattin Brothers Company, The. Marietta, O.
1912. Pawling & Harnishfeger. Milwaukee, Wis.
1896. Paxson Company, J. W. Pier 45, Philadelphia, Pa.
1908. Pease Foundry Company, Limited. 36 Queen Street, East, Toronto, Ont.
1913. Peerless Foundry, The. George F. Dana, Proprietor, Hamilton, O.
1912. Peltz, H. L. 939 West Moulton Street, Bloomington, Ill.
1913. Pendleton, J. C. 403 South Wright Street, Champaign, Ill.
1907. Pennsylvania Casting and Machine Company. Preble Avenue, Pittsburgh, Pa., N. S.
1896. Penton, John A. Penton Building, Cleveland, O.
1913. Perrott, R. O. Secretary, The American Clay Machinery Company, Bucyrus, O.
1909. Peterson Company, T. J. Lees Building, Chicago, Ill.
1909. Philadelphia Chaplet and Manufacturing Company. Wissahickon, Philadelphia, Pa.
1912. Philadelphia Sash Weight Works. Twenty-second Street and Glenwood Avenue, Philadelphia, Pa.
1909. Phillips & Buttorf Manufacturing Company. Nashville, Tenn.
1900. Phillips & McLaren Company. Pittsburgh, Pa.
1909. Pickands, Brown & Co. Chicago, Ill.
1896. Pickands, Mather & Co. Cleveland, O.

1912. Piedmont Foundry and Machine Company. Piedmont, W. Va.
1896. Pilling & Crane. Girard Trust Building, Philadelphia, Pa.
1902. Pittsburgh Emery Wheel Company. Park Building, Pittsburgh, Pa.
1911. Pittsburgh Foundry and Machine Company. Pittsburgh, Pa.
1903. Porter, Dr. John J. Box 664, Staunton, Va.
1909. Portland Stove Foundry Company. Portland, Me.
1896. Potter Printing Press Company. Plainfield, N. J.
1902. Poughkeepsie Foundry and Machine Company. Poughkeepsie, N. Y.
1907. Pratt & Cady Company. Hartford, Conn.
1904. Pressed Steel Car Company. Pittsburgh, Pa.
1911. Primos Chemical Company. Primos, Pa.
1906. Pulaski Iron Company. Real Estate Trust Company, Philadelphia, Pa.

1906. Rathbone, Sard & Co. Albany, N. Y.
1907. Raymond Manufacturing Company of Guelph, Limited, The. Guelph, Ont.
1912. Read Machinery Company, Incorporated, The. York, Pa.
1912. Reed-Prentice Company. Worcester, Mass.
1906. Reeves & Co., Incorporated. Columbus, Ind.
1908. Redington, Patrick. 79 Perry Street, Salem, O.
1912. Reid Gas Engine Company, Joseph. Oil City, Pa.
1906. Remington Typewriter Company. Ilion, N. Y.
1913. Richardson & Boynton Company. Dover, N. J.
1909. Richmond Foundry and Manufacturing Company. Richmond, Va.
1910. Riverside Iron Works. One Hundred and Sixth Street and Buffalo Avenue, Chicago, Ill.
1907. Robbins & Meyers Company, The. Springfield, O.
1907. Robeson Process Company. Au Sable Forks, N. Y.
1909. Robinson, Louis G. Harrison Building, Cincinnati, O.
1910. Rock Island Plow Company. Rock Island, Ill.

1907. Rockwell Furnace Company. 26 Cortlandt Street, New York City.

1896. Rogers, Brown & Co. Cincinnati, O.

1912. Ronceray, E. 9 Rue des Envierges, Paris, France.

1904. Rosedale Foundry and Machine Company. Washington and Preble Avenues, Pittsburgh, Pa., N. S.

1898. Ross-Meehan Foundry Company. Chattanooga, Tenn.

1907. Ross-Tacony Crucible Company. Tacony, Philadelphia, Pa.

1907. Rothe, Joseph F. Green Bay Iron and Brass Foundry, Green Bay, Wis.

1908. Rumely Company, M. La Porte, Ind.

1908. Russell & Co., The. Massillon, O.

1913. Ryder-Ericsson Engine Company. 20 Murray Street, New York City.

1896. St. Paul Foundry Company. St. Paul, Minn.

1909. Sand Mixing Machine Company. 220 Broadway, New York City.

1907. Sandy Hill Iron and Brass Works. Hudson Falls, N. Y.

1901. Sargent & Co. New Haven, Conn.

1903. Saunders & Franklin. P. O. Box 226, Olneyville, Providence, R. I.

1912. Sawyer-Massey Company, Limited. Hamilton, Ont.

1906. Schaum & Uhlinger. Glenwood Avenue and Second Street, Philadelphia, Pa.

1910. Schreiber, William A. 626 June Street, Cincinnati, O.

1908. Schwartz, Henry A. 542 Tibbs Avenue, Indianapolis, Ind.

1910. Seager Engine Works. Lansing, Mich.

1896. Seaman-Sleeth Company. Arsenal Station, Pittsburgh, Pa.

1906. Sellers & Co., Incorporated, William. 1600 Hamilton Street, Philadelphia, Pa.

1911. Sessions Foundry Company. Bristol, Conn.

1909. Sheckler, M. O. Union Switch and Signal Company, Swissvale, Pa.

1896. Sheppard & Co., Isaac A. Fourth Street and Montgomery Avenue, Philadelphia, Pa.

1900. Sheriffs Manufacturing Company. Milwaukee, Wis.

1907. Sherwin, John. President, Chicago Hardware Foundry Company, North Chicago, Ill.

1905. Sill Stove Works. Rochester, N. Y.

1900. Simmons Manufacturing Company, The. Kenosha, Wis.

1913. Simpson Heater Company. Newark, O.

1899. Sly Manufacturing Company, The W. W. Cleveland, O.

1908. Smart Manufacturing Company, The James. Brockville, Ont.

1912. Smedley Steam Pump Company. Dubuque, Ia.

1902. Smith & Anthony Company. 52 Union Street, Boston, Mass.

1907. Smith & Caffrey. Syracuse, N. Y.

1913. Smith & Sons Manufacturing Company, The. Kansas City, Mo.

1908. Smith Company, The H. B. Westfield, Mass.

1896. Smith Foundry Supply Company, The J. D. Cleveland, O.

1911. Smith Manufacturing Company, The A. P. East Orange, N. J.

1913. Smith Manufacturing Company, The Philip. Sidney, O.

1897. Smith's Falls Malleable Castings Company, Limited. Smith's Falls, Ont.

1912. Snead & Co. Iron Works, Incorporated, The. Jersey City, N. J.

1899. Souther, Henry. Hartford, Conn.

1896. Springfield Facing Company. Springfield, Mass.

1913. Spuck Iron and Foundry Company. St. Louis, Mo.

1910. Standard Foundry Company. 22 Chene Street, Detroit, Mich.

1906. Standard Ideal Company, Limited, The. Port Hope, Ont.

1911. Standard Linseed Company. Cleveland, O.

1907. Standard Malleable Iron Company. Muskegon, Mich.

1912. Stanley Works, The. Bridgewater, Mass.

1911. Starke's Dixie Plow Works. Richmond, Va.

1902. STEAD, J. E. Queen's Terrace, Middlesbrough, England.
1911. STEEL & RADIATION, LIMITED. Toronto, Ont.
1912. STEEN, A. B. Manager, National Transit Shops, Oil City, Pa.
1902. STEINWAY & SONS. Riker Avenue, Steinway, L. I., N. Y.
1909. STIRLING WHEELBARROW COMPANY. Milwaukee, Wis.
1900. STERRIT-THOMAS FOUNDRY COMPANY. Thirty-second and Smallman Streets, Pittsburgh, Pa.
1908. STEWART, CHARLES E. President, The James Stewart Manufacturing Company, Limited, Woodstock, Ont.
1905. STILLMAN, PROF. THOMAS B. Stevens Institute of Technology, Hoboken, N. J.
1912. STINE COMPANY, THE J. C. Tyrone, Pa.
1909. STOUGHTON, BRADLEY. 29 West Thirty-ninth Street, New York City.
1906. STRAIGHT LINE ENGINE COMPANY, THE. Syracuse, N. Y.
1912. STUDEBACKER CORPORATION, THE. South Bend, Ind.
1899. STUPAKOFF, S. H. Mechanical Engineer, 545 Turret Street, Pittsburgh, Pa.
1896. STURTEVANT COMPANY, B. F. Hyde Park, Mass.
1908. STEVENS, FREDERICK B. Detroit, Mich.
1907. SULLIVAN MACHINERY COMPANY. Cleremont, N. H.
1909. SWEET & DOYLE FOUNDRY AND MACHINE COMPANY. Green Island, N. Y.
1908. SWETT IRON WORKS, A. L. Medina, N. Y.
1906. SYMINGTON COMPANY, THE T. H. Rochester, N. Y.
1896. SYRACUSE CHILLED PLOW COMPANY. Syracuse, N. Y.

1896. TABOR MANUFACTURING COMPANY, THE. 1740 Hamilton Street, Philadelphia, Pa.
1906. TARRANT FOUNDRY COMPANY. 369 West Indiana Street, Chicago, Ill.
1906. TAYLOR, ELLSWORTH M. 30 Broad Street, New York City.
1908. TAYLOR & CO. Morgan and Norman Avenues, Brooklyn, N. Y.
1907. TAYLOR & FENN COMPANY, THE. Hartford, Conn.
1908. TAYLOR COMPANY, W. P. 218 Ellicott Square, Buffalo, N. Y.

1907. Taylor-Forbes Company, Limited. Guelph, Ont.
1911. Taylor Iron and Steel Company. High Bridge, N. J.
1896. Taylor-Wilson Manufacturing Company. McKees Rocks, Pa.
1898. Tennessee Coal, Iron and Railroad Company. Birmingham, Ala.
1912. Thatcher Furnace Company. 110 Beekman Street, New York City.
1912. Thornley, F. C. General Superintendent, Robbins Belt Conveying Company, Passaic, N. J.
1911. Tilghman-Brooksbanks Sand Blast Company. 1126 South Eleventh Street, Philadelphia, Pa.
1911. Titanium Alloy Manufacturing Company, The. Niagara Falls, N. Y.
1907. Tittle, C. L. Blairsville, Pa.
1907. Tod Company, The William. Youngstown, O.
1912. Toledo Steel Casting Company, The. Toledo, O.
1912. Tollaud, John J. Jenkins Brothers, Limited, 103 St. Remi Street, St. Henry, P. Q.
1911. Topton Foundry and Machine Company. Topton, Pa.
1900. Touceda, Enrique. Albany, N. Y.
1910. Treadwell Engineering Company. Easton, Pa.
1905. Trenton Malleable Iron Company. Trenton, N. J.
1912. Tropenas Converter Company. 50 Church Street, New York City.
1911. Trowbridge, L. L. Reading Car Wheel Company, Reading, Pa.
1905. Turner & Seymour Manufacturing Company. Torrington, Conn.

1901. Union Foundry and Machine Company. West Carson Street, S. S., Pittsburgh, Pa.
1909. Union Foundry Company. Anniston, Ala.
1907. Union Manufacturing Company. New Britain, Conn.
1911. Union Sanitary Manufacturing Company. Noblesville, Ind.
1910. Union Steam Pump Company. Battle Creek, Mich.
1907. Union Steel Casting Company. Sixty-first Street and A. V. Ry., Pittsburgh, Pa.

1896. UNION STOVE WORKS, THE. Peekskill, N. Y.
1896. UNITED ENGINEERING AND FOUNDRY COMPANY. Pittsburgh, Pa.
1896. UNITED ENGINEERING AND FOUNDRY COMPANY. Lloyd Booth Department, Youngstown, O.
1907. UNITED IRON WORKS COMPANY. Springfield, Mo.
1909. UNITED STATES CAST IRON AND PIPE COMPANY. Bessemer, Ala.
1913. UNITED STATES CAST IRON PIPE AND FOUNDRY COMPANY. Burlington, N. J.
1906. UNITED STATES GRAPHITE COMPANY, THE. Saginaw, Mich.
1907. UNIVERSAL CASTER AND FOUNDRY COMPANY. 108 Adams Street, Newark, N. J.
1911. UNIVERSITY OF KANSAS. Lawrence, Kan.
1906. UTICA HEATER COMPANY. Utica, N. Y.

1907. VALENTINE, C. 137 Mullin Street, Watertown, N. Y.
1911. VALLEY IRON WORKS. Williamsport, Pa.
1908. VANCOUVER ENGINEERING WORKS, LIMITED. Vancouver, B. C.
1907. VANDERMAN MANUFACTURING COMPANY, THE. Willimantic, Conn.
1912. VAN WIE, E. G. Superintendent, Detroit Stove Works, Detroit, Mich.
1908. VERITY PLOW COMPANY, LIMITED. Brantford, Ont.
1912. VETTER, JOHN. 1080 Fifth Avenue, New York City.
1903. VIRGINIA IRON, COAL AND COKE COMPANY. Roanoke, Va.
1909. VULCAN IRON WORKS. Wilkes-Barre, Pa.
1907. VULCAN PLOW COMPANY. Evansville, Ind.

1896. WALKER & PRATT MANUFACTURING COMPANY. 31 Union Street, Boston, Mass.
1907. WALKER FOUNDRY COMPANY. Erie, Pa.
1907. WALWORTH MANUFACTURING COMPANY. 132 Federal Street, Boston, Mass.
1910. WARDEN, KING, LIMITED. Montreal, P. Q.
1912. WARREN COKE COMPANY, M. H. Levee and Rutger Streets, St. Louis, Mo.

1912. WARREN, JAMES. Treasurer, Wheeler Foundry Company, Worcester, Mass.
1913. WARREN STEEL CASTING COMPANY. 204 Liggett Building, St. Louis, Mo.
1900. WARWICK IRON AND STEEL COMPANY. Pottstown, Pa.
1896. WASHINGTON COAL AND COKE COMPANY. 7 Wood Street, Pittsburgh, Pa.
1912. WATERBURY CASTINGS COMPANY, THE. Waterbury, Conn.
1908. WATEROUS, C. H. Waterous Engine Works Company, Brantford, Ont.
1909. WATSON, C. H. Brass Foundry and Machine Company, Lenoir, Tenn.
1903. WATTS, GEORGE W. Works Manager, Canada Foundry Company, Toronto, Ont.
1911. WAYNE AGRICULTURAL WORKS. Goldsboro, N. C.
1909. WEBSTER MANUFACTURING COMPANY, THE. Tiffin, O.
1912. WEIR STOVE COMPANY. Taunton, Mass.
1907. WELSH, E. C. Northern and Western Railroad, Roanoke, Va.
1896. WESTERN FOUNDRY COMPANY, THE. 3634 Kedzie Avenue, Chicago, Ill.
1908. WESTERN FOUNDRY COMPANY, LIMITED, THE. Wingham, Ont.
1913. WESTERN GAS ENGINE CORPORATION. 900 North Main Street, Los Angeles, Cal.
1912. WESTERN STEEL AND IRON COMPANY, LIMITED, THE. Winnipeg, Manitoba.
1896. WESTINGHOUSE AIR BRAKE COMPANY. Pittsburgh, Pa.
1896. WESTINGHOUSE MACHINE COMPANY. East Pittsburgh, Pa.
1906. WESTMORELAND MALLEABLE IRON COMPANY, LIMITED. Westmoreland, N. Y.
1913. WESTOVER, JOHN, INCORPORATED. Lincoln, Neb.
1908. WEST SIDE FOUNDRY COMPANY. Troy, N. Y.
1908. WEST STEEL CASTING COMPANY, THE. 805 East Seventieth Street, Cleveland, O.
1911. WESTWICK & SON, JOHN. Claude Street, Galena, Ill.

1898. WHEELING MOLD AND FOUNDRY COMPANY. Wheeling, W. Va.
1911. WHITE & SONS COMPANY, THE GEORGE. London, Ont.
1908. WHITE COMPANY, J. S. Pawtucket, R. I.
1912. WHITE DENTAL MANUFACTURING COMPANY, THE S. S. Prince Bay, N. Y.
1896. WHITEHEAD BROTHERS COMPANY. 537 West Twenty-seventh Street, New York City.
1911. WHITE'S IRON WORKS, FRED. J. 462 Maine Avenue, S. W., Washington, D. C.
1910. WHITE WARNER COMPANY. Taunton, Mass.
1896. WHITING FOUNDRY EQUIPMENT COMPANY. Harvey, Ill.
1896. WHITIN MACHINE COMPANY. Whitinsville, Mass.
1902. WIEDEMANN, A. Gremsdorf, Liegnitz, Silesia, Germany.
1906. WILKINSON, S. 512 Franklin Avenue, Ellwood City, Pa.
1913. WILLARD, WILLIAM G. O'Fallon, Ill.
1911. WILMINGTON IRON WORKS. Wilmington, N. C.
1908. WILSON, JOSEPH J. 35 Chandler Avenue, Detroit, Mich.
1896. WITHERLY, FREDERICK B. Bunker Hill Iron Foundry, Charlestown, Mass.
1897. WOLFF MANUFACTURING COMPANY, L. Hoyne and Carrol Streets, Chicago, Ill.
1907. WONHAM, SANGER & BATES. 30 Church Street, New York City.
1896. WOOD, WALTER. 400 Chestnut Street, Philadelphia, Pa.
1910. WOODRUFF & EDWARDS COMPANY. Elgin, Ill.
1911 WOODRUFF MACHINERY MANUFACTURING COMPANY. Winder, Ga.
1903 WOODWARD IRON COMPANY. Woodward, Ala.
1907 WORTMAN & WARD COMPANY, LIMITED, THE. London, Ont.

1898 YALE & TOWNE MANUFACTURING COMPANY, THE. Stamford, Conn.
1912 YORK MANUFACTURING COMPANY. York, Pa.

1912. ZIPPLER, FRANCIS J. Keystone Tuyerage Company, Incorporated, Reading, Pa.

SUMMARY.

Elected to Membership.	No. of Members.
1896	60
1897	9
1898	13
1899	7
1900	23
1901	10
1902	10
1903	10
1904	15
1905	17
1906	42
1907	114
1908	85
1909	48
1910	49
1911	57
1912	96
1913 to date of publication	37
	702
Honorary Members	13
Total Membership, May, 1913	715

GEOGRAPHICAL DISTRIBUTION OF MEMBERSHIP.

UNITED STATES.

ALABAMA.

Anniston: Union Foundry Company.

Bessemer: U. S. Cast Iron and Pipe Company.

Birmingham: The Alabama Company; Birmingham Machine and Foundry Company; Tennessee Coal, Iron and Railroad Company.

Sheffield: Alex. T. Drysdale.

Woodward: Woodward Iron Company.

ARIZONA.

Globe: Globe Foundry and Machine Company.

CALIFORNIA.

Los Angeles: Western Gas Engine Corporation.

San Francisco: Columbia Steel Company; James Graham Manufacturing Company; Pacific Foundry Company.

COLORADO.

Denver: Colorado Iron Works Company.

Pueblo: The Colorado Fuel and Iron Company.

CONNECTICUT.

Ansonia: Farrel Foundry and Machine Company.

Branford: Malleable Iron Fittings Company.

Bridgeport: Crane Valve Company.

Bristol: Sessions Foundry Company.

Derby: Birmingham Iron Foundry.

Hartford: Hartford Laboratory; Pratt & Cady Company; Henry Souther; The Taylor & Fenn Company.

Middletown: W. & B. Douglas.

New Britain: Edward B. Alling; P. & F. Corbin; Davenport & Keeler; Landers, Frary & Clark; North & Judd Manufacturing Company; Russell & Erwin Manufacturing Company; Union Manufacturing Company.

New Haven: S. H. Barnum; The McLagon Foundry; The New Haven Sand Blast Company; Sargent & Co.

New London: The Hopson & Chapin Manufacturing Company.

Stamford: The Yale & Towne Manufacturing Company.

CONNECTICUT.—*Continued.*

Torrington: Turner & Seymour Manufacturing Company.

Waterbury: The Manufacturers Foundry Company; The Waterbury Castings Company.

Willimantic: The Vanderman Manufacturing Company.

DELAWARE.

Wilmington: Hillis & Jones Company; Lobdell Car Wheel Company.

DISTRICT OF COLUMBIA.

Washington: Frederick J. White's Iron Works.

GEORGIA.

Augusta: Lombard Iron Works and Supply Company.

Columbus: Columbus Iron Works Company; Golden's Foundry and Machine Company.

Gainesville: Gainesville Iron Works.

Moreland: E. N. Camp & Sons Company.

Winder: Woodruff Machine and Manufacturing Company.

IDAHO.

Moscow: Idaho National Harvester Company.

ILLINOIS.

Belleville: Belleville Stove and Range Company; Orbon Stove and Range Company.

Bloomington: P. H. MaGirl; H. L. Pelz.

Bradley: David Bradley Manufacturing Company.

Champaign: Robert Kennedy; J. C. Pendleton.

Chicago: Aermotor Company; American Steel Foundries; S. Birkenstein & Sons; H. W. Caldwell & Sons Co.; Chicago Pneumatic Tool Company; Chicago Steel Foundry Company; Crane Company; Ferguson & Lange Foundry Company; The Foundry and Machine Exhibition Company; The Garden City Sand Company; Greenlee Foundry Company; Griffin Wheel Company; Illinois Malleable Iron Company; W. A. Jones (Honorary Member); W. A. Jones Foundry and Machine Company; Kroeschell Brothers; Link Belt Company; T. J. Peterson Company; Pickands, Brown & Co.; Riverside Iron Works; John Sherwin (Chicago Hardware Foundry Company); Tarrant Foundry Company; The Western Foundry Company; Chris. J. Wolff (Honorary Member); L. Wolff Manufacturing Company.

Decatur: Philip Mueller.

East St. Louis: Missouri Malleable Iron Company.

Elgin: Woodruff & Edwards Company.

Freeport: Arcade Manufacturing Company.

Galena: John Westwick & Son.

Granite City: R. A. Bull.

ILLINOIS.—*Continued.*

Harvey: Whiting Foundry Equipment Company.

Joliet: Moore Brothers Company.

Kewanee: Kewanee Boiler Company; National Tube Company.

Moline: Deere & Co.; Moline Plow Company.

O'Fallon: William G. Willard.

Quincy: Central Iron Works; Excelsior Stove and Manufacturing Company.

Rock Island: Rock Island Plow Company.

INDIANA.

Columbus: Reeves & Co.

Connersville: Connersville Blower Company.

Evansville: The Grote Manufacturing Company; Vulcan Plow Company.

Fort Wayne: The Bass Foundry and Machine Company.

Goshen: Kelley Foundry and Machine Company.

Indianapolis: Inter-State Car Company; Henry A. Schwartz.

La Porte: M. Rumely Company.

Marion: The Marion Malleable Iron Works.

Mishawaka: Dodge Manufacturing Company.

Noblesville: Union Sanitary Manufacturing Company.

South Bend: The Studebacker Corporation.

IOWA.

Bettendorf: Bettendorf Axle Company.

Burlington: Murray Iron Works Company.

Davenport: Davenport Machine and Foundry Company; French and Hecht.

Dubuque: Smedley Steam Pump Works.

Fairfield: Iowa Malleable Iron Company.

Marshalltown: The Lennox Furnace Company.

KANSAS.

Lawrence: University of Kansas.

KENTUCKY.

Louisville: E. M. Drummond.

Newport: Newport Sand Bank Company.

Paducah: Lack Malleable Iron Company.

Winchester: Eagle Casting Company.

MAINE.

Portland: Portland Stove and Foundry Company.

MARYLAND.

Baltimore: Baltimore Malleable Iron and Steel Castings Company and P. Kennedy's Foundry; Stewart R. Carr & Co.; Jones Hollow Ware Company; James J. Lacy Company.

Hagerstown: Thos. W. Pangborn Company.

MASSACHUSETTS.

Barre: Chas. G. Allen Company.

Boston: Gibby Foundry Company; Hunt-Spiller Company; Prof. Edw. A. Johnson; Geo. H. Lincoln Company; Arthur D. Little, Incorporated; Smith & Anthony; A. W. Walker (Honorary Member); Walker & Pratt Manufacturing Company; Walworth Manufacturing Company.

Bridgewater: The Stanley Works.

Cambridgeport: Barbour & Stockwell Company; Broadway Iron Foundry.

Charlestown: Frederick B. Witherly.

Chelsea: Magee Furnace Company.

Chicopee Falls: Lamb Knitting Machine Company.

East Cambridge: Arthur F. Murray.

Everett: James S. Katzmann.

Fitchburg: L. H. Goodnow Foundry Company.

Hopedale: H. W. Bracken.

Hyde Park: B. F. Sturtevant Company.

Indian Orchard: Chapman Valve Manufacturing Company.

Milford: Milford Iron Foundry.

North Adams: James Hunter Machine Company.

Pittsfield: Berkshire Pattern Company; General Electric Company.

Springfield: Emerson Laboratories; Springfield Facing Company.

Taunton: Weir Stove Company; White-Warner Company.

Westfield: H. B. Smith Company.

West Lynn: General Electric Company.

Whitinsville: Whitin Machine Company.

Worcester: Norton Company; Reed-Prentice Company; James Warren.

MICHIGAN.

Battle Creek: Union Steam Pump Company.

Bay City: Industrial Works; McKinnon Boiler and Machine Company.

Benton Harbor: Benton Harbor Malleable Foundry Company.

Buchanan: Buchanan Electric Steel Company.

Detroit: American Blower Company; F. L. Bromley; The Detroit Steel Casting Company; The Detroit Testing Laboratories; Enterprise Foundry Company; The Ideal Manufacturing Company; H. M. Lane; Michigan Steel Castings Company; Michigan Stove Company; Murphy Iron Works; Northern Engineering Works; Parker Brothers Company, Limited; Standard Foundry Company; Frederick B. Stevens; E. G. Van Wie; Arthur T. Waterfall (Honorary Member); Joseph J. Wilson.

MICHIGAN.—*Continued.*

Dowagiac: Estate of P. D. Beckwith.
Flint: Michigan Motor Castings Company.
Grand Rapids: Oliver Machinery Company.
Kalamazoo: D. R. Curtenius.
Lansing: Novo Engine Company; Seager Engine Works.
Marquette: Lake Shore Engine Works.
Muskegon: Standard Malleable Iron Company.
Saginaw: The U. S. Graphite Company.

MINNESOTA.

Minneapolis: Keller Manufacturing Company; Minneapolis Steel and Machinery Company.

St. Paul: American Hoist and Derrick Company; Northern Malleable Iron Company; St. Paul Foundry Company.

MISSOURI.

Kansas City: The Smith & Sons Manufacturing Company.

St. Louis: Bridge and Beach Manufacturing Company; Buck Stove and Range Company; Carondelet Foundry Company; Commonwealth Steel Company; Curtis & Co. Manufacturing Company; A. S. Dowler (Webster Groves); Green's Car Wheel Manufacturing Company; Alex. Kilpatrick & Sons Foundry Company; Liberty Foundry Company; Materne Manufacturing Company; Warren Steel Casting Company; M. H. Warren Coke Company; Spuck Iron and Foundry Company.

Springfield: United Iron Works Company.

MONTANA.

Anaconda: Anaconda Copper Mining Company.

NEBRASKA.

Beatrice: Dempster Mill Manufacturing Company.
Lincoln: John Westover, Incorporated.

NEVADA.

Reno: Nevada Engineering Works.

NEW HAMPSHIRE.

Claremont: Sullivan Machinery Company.
Laconia: The Laconia Car Company Works.

NEW JERSEY.

Burlington: U. S. Cast Iron Pipe and Foundry Company.
Dover: Richardson and Boynton Company.
East Orange: The A. P. Smith Manufacturing Company.

NEW JERSEY.—*Continued.*

Elizabeth: Samuel L. Moore & Sons Corporation.

Flemington: Foran Foundry and Manufacturing Company.

Florence: Florence Iron Works.

Hackettstown: American Saw Mill Machinery Company.

High Bridge: Taylor Iron and Steel Company.

Hoboken: Prof. Thos. B. Stillman.

Jersey City: Wm. M. Crane Company; The M. W. Kellogg Company; The Snead & Co. Iron Works, Incorporated.

Mahwah: American Brake Shoe and Foundry Company; P. Munnoch.

Newark: The Barlow Foundry Company; Oscar Barnett Foundry Company; Maher & Flockhart; Meeker Foundry Company; Universal Caster and Foundry Company.

New Brunswick: Empire Foundry Company.

Passaic: F. C. Thornley.

Paterson: McNab & Harlin Manufacturing Company.

Perth Amboy: F. L. Antisell.

Plainfield: Potter Printing Press Company.

Trenton: Jonathan Bartley Crucible Company; J. L. Mott Company; The Trenton Malleable Iron Company.

Watchung: Dr. Richard Moldenke (Honorary Member).

NEW YORK.

Albany: Rathbone, Sard & Co.; Enrique Touceda.

Auburn: McIntosh, Seymour & Co.

Au Sable Forks: Robeson Process Company.

Batavia: The Johnston Harvester Company.

Belmont: Clark Brothers.

Binghamton: The Fairbanks Company.

Brooklyn: The Burr & Houston Company; Fulton Foundry and Machine Company; Hauck Manufacturing Company; Wm. H. Parry; Taylor & Co.

Buffalo: Acme Steel and Malleable Iron Company; Willis Brown (Honorary Member); Buffalo Forge Company; Buffalo Foundry and Machine Company; Buffalo Scale Company; James W. Gibney; Frank E. Hall; E. E. Joseph; C. E. Knoeppel; National Core Oil Company; W. P. Taylor.

Carthage: W. McA. Gilbert.

Cortland: Cooper Brothers.

Dunkirk: B. F. Evans.

Elmira: Elmira Foundry Company; Archie M. Loudon.

Goshen: J. H. Newbury.

Green Island: Sweet & Doyle Foundry and Machine Company.

Hoosick Falls: James A. Beckett; Major Chas. C. Jamieson.

Hudson Falls: Sandy Hill Iron and Brass Works.

Ilion: Remington Typewriter Company.

Irvington: Lord & Burnham Company.

NEW YORK.—*Continued.*

Ithaca: Morse Chain Company.

Lockport: A. M. Mattice.

Long Island City: Jos. McGee Iron and Brass Foundry Company.

Lyon Mountain: James Brakes.

Manlius: S. Cheney & Son.

Matteawan: The Green Fuel Economizer Company.

Medina: A. L. Swett Iron Works.

Monroe: The Newbury Manufacturing Company.

Newburg: Alberger Pump and Condenser Company.

New York City: Andrew Allan, Jr.; Central Foundry Company; Debevoise-Anderson Company; Harrington Emerson; Benj. Fox's Sons; The Goldschmid Thermit Company; *The Iron Age*; Wm. H. Jackson Company; T. P. Kelley & Co.; Lidgerwood Manufacturing Company; The McCrum-Howell Company; Mumford Molding Machine Company; Rockwell Furnace Company; Ryder-Ericsson Engine Company; The Sand Mixing Machine Company; Steinway & Sons; Bradley Stoughton; Ellsworth M. Taylor; Thatcher Furnace Company; Tropenas Converter Company; John Vetter; Whitehead Brothers Company; Wonham, Sanger & Bates.

Niagara Falls: The Titanium Alloys Manufacturing Company.

Ogdensburg: Jos. E. Fell.

Pearl River: Dexter Folder Company.

Peekskill: The Union Stove Works.

Pelham: Samuel D. I. Emerson.

Port Chester: Abendroth Brothers.

Poughkeepsie: Adriance, Platt & Co.; Poughkeepsie Foundry and Machine Company.

Prince Bay: The S. S. White Dental Manufacturing Company.

Rochester: American Laundry Machinery Manufacturing Company; American Wood Working Machinery Company; Co-Operative Foundry Company; Gleason Works; Sill Stove Company; T. H. Symington Company.

Schenectady: General Electric Company; Martin F. Murphy.

Seneca Falls: The Goulds Manufacturing Company.

Syracuse: Smith & Caffrey Company; The Straight Line Engine Company; Syracuse Chilled Plow Company.

Troy: Fuller & Warren Company; West Side Foundry Company.

Utica: International Heater Company; Utica Heater Company.

Waterford: John Knickerbacker.

Watertown: The New York Air Brake Company; C. Valentine.

Westmoreland: Westmoreland Malleable Iron Company, Limited.

West New Brighton: C. W. Hunt Company.

NORTH CAROLINA.

Goldsboro: Dewey Brothers; Wayne Agricultural Works.

Wilmington: Wilmington Iron Works.

OHIO.

Akron: The Atlantic Foundry Company.

Alliance: Morgan Engineering Company.

Bedford: Best Foundry Company.

Bucyrus: Bucyrus Steel Casting Company; R. O. Perrott.

Canton: J. H. McLain Company; Novelty Iron Company.

Chagrin Falls: Ober Manufacturing Company.

Cincinnati: Buckeye Foundry Company; F. M. Eaton; The Haven Malleable Castings Company; The Hill & Griffiths Company; The Modern Foundry Company; The Monitor Stove and Range Company; The John B. Morris Foundry Company; The J. A. Oberhelman Foundry Company; The S. Obermayer Company; Louis G. Robinson; Rogers, Brown & Co.; Wm. A. Schreiber.

Cleveland: The Acme Foundry Company; A. O. Backert; The Berkshire Manufacturing Company; Fred. Blundell; The Chisholm & Moore Manufacturing Company; The City Foundry Company; Crowell & Murray; Dover Fire Brick Company; Federal Foundry Supply Company; Ferro Machine and Foundry Company; Benj. D. Fuller; The Gardner Printing Company; The Interstate Foundry Company; The Madison Foundry Company; C. M. Miller; The Ohio Foundry Company; The Osborn Manufacturing Company; Otis Steel Company; The Palmers & De Mooy Foundry Company; John A. Penton; Pickands, Mather & Co.; The W. W. Sly Manufacturing Company; J. D. Smith Foundry Supply Company; Standard Linseed Oil Company; Thos. D. West (Honorary Member); The West Steel Casting Company.

Columbiana: Enterprise Manufacturing Company.

Columbus: The Buckeye Steel Casting Company; The Columbus Iron and Steel Company; The Columbus Machine and Tool Company; The Kinnear Manufacturing Company; The Ohio Malleable Iron Company; J. F. Mooney.

Coshocton: Chas. M. Aland; James B. Clow & Sons.

Dayton: Julian Gaible.

Galion: A. M. Freese & Co.; The Galion Iron Works Company.

Girard: The Girard Iron Company.

Hamilton: The Estate Stove Company; The Niles Tool Works; The Peerless Foundry.

Hillsboro: The C. S. Bell Company.

Leetonia: McKeefrey & Co.

Lima: Lima Locomotive Company.

Marietta: The Pattin Brothers Company.

Marion: The Marion Steam Shovel Company.

Massillon: The Russell & Co.

Medina: The Medina Foundry Company.

Piqua: The Favorite Stove and Range Company.

Plymouth: The Heath Foundry and Manufacturing Company.

Salem: Buckeye Engine Company; The Deming Company; The National Sanitary Manufacturing Company; Patrick Redington.

OHIO.—*Continued.*

Sandusky: The Bay View Foundry Company.

Sidney: The Philip Smith Manufacturing Company.

Springfield: American Seeding Machine Company; French & Hecht; The Hennessy Foundry Company; The Robbins & Myers Company.

Tiffin: The Webster Manufacturing Company.

Toledo: The National Supply Company; The Toledo Steel Casting Company.

Willoughby: The American Clay Machinery Company.

Youngstown: The Wm. Tod Company; United Engineering and Foundry Company; The Youngstown Bronze and Iron Company.

Zanesville: Interstate Sand Company.

OKLAHOMA.

Ponca City: W. H. McFadden (Honorary Member).

OREGON.

Portland: Independent Foundry Company.

PENNSYLVANIA.

Altoona: Edward McLean; P. Kreuzpointner.

Ambridge: L. E. Montgomery.

Avonmore: The National Roll and Foundry Company.

Berwick: American Car and Foundry Company.

Blairsville: Blairsville Enameled Ware Company; L. C. Tittle.

Braddock: Braddock Machine and Foundry Company; Geo. England (Carnegie Steel Company).

Catasauqua: Crane Iron Works.

Chester: Frank Francis.

Danville: Danville Foundry and Machine Company.

Dubois: Adrian Furnace Company.

Easton: The Hawley Down Draft Furnace Company; Treadwell Engineering Company.

Elizabethtown: A. Buch's Sons.

Ellwood City: S. Wilkinson.

Emaus: John D. Ormrod.

Erie: H. E. Diller; Erie Engine Works; Erie Foundry Company; Erie Malleable Company; Jarecki Manufacturing Company; Metric Metal Works; Walker Foundry Company.

Graceton: Graceton Coke Company.

Harrisburg: Harrisburg Foundry and Machine Company.

Kennett Square: J. J. Crozier.

Kittanning: Kittanning Iron and Steel Manufacturing Company.

Lancaster: Carbon Steel Casting Company.

Lansdale: Central Radiator Company.

Lebanon: The Buchanan Foundry Company; Lebanon Steel Foundry.

PENNSYLVANIA.—*Continued.*

McKeesport: Fort Pitt Steel Castings Company.

McKees Rocks: Fort Pitt Malleable Iron Company; Taylor-Wilson Manufacturing Company.

Meadville: Meadville Malleable Iron Company.

Monessen: Monessen Foundry and Machine Company.

New Brighton: Dawes & Miller Works.

Oil City: Oil Well Supply Company: Jas. Reid Gas Engine Company; A. B. Steen.

Philadelphia: Atlantic Radiator Company; American Engineering Company; Booth, Garret & Blair; John Braun & Sons; E. E. Brown & Co.; Abram Cox Stove Company; Alfred Crook; Geo. C. Davis; Thos. Devlin Manufacturing Company; The Enterprise Manufacturing Company of Pennsylvania; Eynon-Evans Manufacturing Company; Stanley G. Flagg, Jr. (Honorary Member); Stanley G. Flagg & Co.; Girard Iron Works; Harrison Safety Boiler Works; Dr. Edward Kirk; Maryland Steel Company; J. J. Mohr & Son; James Moran; I. P. Morris Company; Nelson Valve Company; Niles-Bement-Pond Company; J. W. Paxson Company; Philadelphia Chaplet and Manufacturing Company; Philadelphia Sash Weight Works; Pilling & Crane; Pulaski Iron Company; Ross-Tacony Crucible Company; Schaum & Uhlinger, Incorporated; Wm. Sellers & Co., Incorporated; Isaac A. Sheppard & Co.; The Tabor Manufacturing Company; Tilghman-Brooksbanks Sand Blast Company; Walter Wood.

Phœnixville: Madco Foundry and Machine Company.

Pittsburgh: American Lumber and Manufacturing Company; American Vanadium Company; Bessemer Coke Company; Clinton Iron and Steel Company; Damascus Bronze Company; Duquesne Steel Foundry Company; Enterprise Sand Company; Epping-Carpenter Company; H. E. Field; Edw. D. Frohman; A. Garrison Foundry Company; M. A. Hanna & Co.; Harbison & Walker Refractories Company; J. H. Hillman & Son; Iron City Sanitary Manufacturing Company; Jamieson Coal and Coke Company; The James Jiles Company; D. G. P. Justice; Charles L. Kirk; W. G. Klaus; C. F. Knowlton; Lawrence Steel Casting Company; Lewis Foundry and Machine Company; John A. Logan; O. M. Mason; The McConway and Torley Company; J. S. McCormick Company; Mesta Machine Company; The Millers Products Company; National Car Wheel Company; National Gear Wheel Foundry; Pennsylvania Casting and Machine Company; Phillips & McLaren Company; Pittsburgh Emery Wheel Company; Pittsburgh Foundry and Machine Company; Pressed Steel Car Company; Rosedale Foundry and Machine Company; Jos. S. Seaman (Honorary Member); Seaman-Sleeth Company; Major Jos. T. Speer (Honorary Member); Sterrit-Thomas Foundry Company; S. H. Stupakoff; Union Foundry and Machine Company; Union Steel Casting Company; United Engineering and Foundry Company; Washington Coal and Coke Company; Westinghouse Air Brake Company; Westinghouse Machine Company.

Pottstown: Warwick Iron and Steel Company.

Primos: Primos Chemical Company.

PENNSYLVANIA.—*Continued.*

Reading: Peter Braucher; Gray Iron Foundry Company; L. L. Trowbridge; F. J. Zipler.

Rochester: Olive Stove Works.

Royersford: Buckwalter Stove Company.

Scranton: International Correspondence Schools.

Shamokin: John Mullen.

South Bethlehem: Bethlehem Foundry and Machine Company; Bethlehem Steel Company.

Swissvale: M. O. Sheckler.

Topton: Topton Foundry and Machine Company.

Tyrone: The J. C. Stine Company.

Waynesboro: Frick Company; L. D. Gilbert; J. W. Little.

Wilkes-Barre: Vulcan Iron Works.

Williamsport: The Eastern Facing Mills; Hermance Machine Company; Valley Iron Works.

York: The Read Machinery Company, Incorporated; York Manufacturing Company.

Zelienople: Herrman Pneumatic Molding Machine Company.

RHODE ISLAND.

Pawtucket: J. S. White Company.

Providence: American and British Manufacturing Company; Barstow Stove Company; Brown & Sharpe Manufacturing Company; Colvin Foundry Company; General Fire Extinguisher Company; New England Butt Company; Saunders & Franklin.

TENNESSEE.

Chattanooga: Judson Buchanan; The Cahill Iron Works; Chattanooga Roofing and Foundry Company; Ross-Meehan Foundry Company.

Clarksville: Clarksville Foundry and Machine Company; A. H. Patch.

Lenoir City: Lenoir Car Works: C. H. Watson.

Nashville: Cumberland Foundry and Manufacturing Company; Gray & Dudley Hardware Company; Phillips & Buttorf Manufacturing Company.

TEXAS.

El Paso: Darbyshire-Harvie Iron and Machine Company.

San Antonio: Alamo Iron Works.

VERMONT.

Montpelier: Lane Manufacturing Company.

St. Johnsbury: E. & T. Fairbanks Company.

VIRGINIA.

Richmond: Richmond Foundry and Machine Company; Starke's Dixie Plow Works.

Roanoke: Virginia Coal, Iron and Coke Company; E. C. Walsh.

Staunton: Dr. John J. Porter.

WEST VIRGINIA.

Fairmont: Fairmont Mining Machinery Company; Helmick Foundry and Machine Company.

Piedmont: Piedmont Foundry and Machine Company.

Powellton: The Mount Carbon Company.

Wheeling: Wheeling Mold and Foundry Company.

WISCONSIN.

Beaver Dam: Malleable Iron Range Company.

Beloit: Berlin Machine Works; Fairbanks, Morse & Co.

Brillion: Brillion Iron Works.

De Pere: The C. A. Lawton Company.

Green Bay: Jos. F. Rothe.

Janesville: The Janesville Machine Company.

Kenosha: The Simmons Manufacturing Company.

La Crosse: La Crosse Plow Company.

Milwaukee: The Bucyrus Company; Chain Belt Company; Dings Electromagnetic Separator Company; A. J. Lindemann & Hoverson Company; David J. McLain; Pawling & Harnishfeger; Sheriff Manufacturing Company; Sterling Wheelbarrow Company.

Port Washington: Gilson Manufacturing Company.

Racine: Belle City Malleable Iron Company; J. I. Case Plow Works.

Sheboygan: J. M. Kohler Sons Company.

Waukesha: I. G. Brown.

CANADA.

BRITISH COLUMBIA.

Vancouver: Vancouver Engineering Works, Limited.

MANITOBA.

Winnipeg: L. L. Anthes (Honorary Member); The Western Steel and Iron Company, Limited.

NEW BRUNSWICK.

St. John: James Fleming.

NOVA SCOTIA.

Amherst: Amherst Foundry Company, Limited.

Halifax: Hillis & Sons, Limited.

ONTARIO.

Aurora: J. Fleury's Sons.

Bowmanville: The Bowmanville Foundry Company, Limited.

Brantford: Cockshutt Plow Company, Limited; Verity Plow Company, Limited; C. H. Waterous.

ONTARIO.—*Continued.*

Brockville: The James Smart Manufacturing Company, Limited.

Carlton Place: Findlay Brothers.

Dundas: The John Bertram Sons Company, Limited.

Galt: Canada Machinery Corporation; Messrs. Galt Malleable Iron Company, Limited; The Galt Stove and Furnace Company, Limited; The Goldie & McCullough Company, Limited; The R. McDougall Company, Limited.

Guelph: The Raymond Manufacturing Company of Guelph, Limited; Taylor-Forbes Company, Limited.

Hamilton: H. V. Hamilton; Sawyer-Massey Company, Limited.

Kingston: Canadian Locomotive Company.

London: The McClary Manufacturing Company; Geo. White & Sons Company, Limited; The Wortman & Ward Company, Limited.

Meaford: J. H. Cleland.

Midland: Midland Engine Works Company.

New Liskeard: H. A. McEwen.

Oshawa: The Ontario Malleable Iron Company, Limited.

Owens Sound: The Wm. Kennedy & Sons Company, Limited.

Port Hope: Standard Ideal Company, Limited.

Preston: Clare Bros. & Co., Limited.

Sarnia: The John Goodison Thresher Company, Limited.

Smith's Falls: The Frost & Wood Company, Limited; Smith's Falls Malleable Castings Company, Limited.

Toronto: Anthes Foundry Company, Limited; The Canadian Rumely Company, Limited; Dodge Manufacturing Company, Limited; W. R. Glasgow; Massey-Harris Company, Limited; Ontario Wind Engine and Pump Company; Pease Foundry Company, Limited; Steel and Radiation, Limited; Geo. W. Watts.

Walkerville: H. O. Kerr.

Welland: Dain Manufacturing Company, Limited.

Weston: J. K. Moffat.

Wingham: The Western Foundry Company, Limited.

Woodstock: Chas. E. Stewart.

QUEBEC.

Buckingham: The Electric Reduction Company, Limited.

Montreal: T. J. Best; Canadian Steel Foundries, Limited; Milton Hersey Company, Limited; John T. Tollaud; Warden, King, Limited.

Terrebonne: The M. Moody & Sons Company.

St. André de Kamouraska: La Compagnie Desjardins.

MEXICO.

San Luis Potosi: J. W. Hall.

EUROPE.

BELGIUM.

Brussels: Jules Brasseur.

ENGLAND.

Birmingham: Prof. Thomas Turner (Honorary Member).
London: Sir Robert Hadfield.
Middlesbrough: J. E. Stead.

FRANCE.

Paris: E. Ronceray, 9 Rue des Envierges.

GERMANY.

Gremsdorf: A. Wiedermann.

SUMMARY

United States.

Alabama	7
Arizona	1
California	4
Colorado	2
Connecticut	27
Delaware	2
Dist. of Columbia	1
Georgia	6
Idaho	1
Illinois	50
Indiana	13
Iowa	7
Kentucky	4
Maine	1
Maryland	5
Massachusetts	36
Michigan	31
Minnesota	5
Missouri	15
Montana	2
Nebraska	2
Nevada	1
New Hampshire	2
New Jersey	28
New York	97
North Carolina	3
Ohio	89
Oklahoma	1
Oregon	1
Pennsylvania	152
Rhode Island	8
Tennessee	11
Texas	2
Vermont	2
Virginia	5
West Virginia	5
Wisconsin	22
Total	650

Canada.

British Columbia	1
Manitoba	2
New Brunswick	1
Nova Scotia	2
Ontario	45
Quebec	7
Total	58

Mexico.

San Luis Potosi	1

Europe.

Belgium	1
England	3
France	1
Germany	1
Total	6
Grand Total	715

VOL. XXI.

INDEX.